SBIR 90-1

OMB Approval No. 2700-0042

Small Business Innovation Research

Program Solicitation

Closing Date: July 16, 1990

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration (NASA) plans, directs, and conducts civil research and development in space and aeronautics.

NASA's goals in space are to develop technology to make operations more effective, to enlarge the range of practical applications of space technology and data, and to investigate the Earth and its immediate surroundings, the natural bodies in our solar system, and the origins and physical processes of the universe. In aeronautics, NASA seeks to improve aerodynamics, structures, engines, and overall performance of aircraft, to make them more efficient, more compatible with the environment, and safer.

NASA SBIR PROGRAM SOLICITATION 90-1

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****** OFFERORS PLEASE READ THESE IMPORTANT NOTICES ******

1. SBIR SOLICITATION REQUIREMENTS VARY AMONG FEDERAL AGENCIES

Proposals developed for another agency may not be responsive to this NASA Solicitation.

2. PROPOSALS MUST MEET SOLICITATION REQUIREMENTS

Offerors should read this Solicitation carefully before developing a Phase I proposal and verify that each proposal conforms to the requirements specified herein, particularly those for which additional emphasis **(bolding)** is indicated. Offerors are advised that certain requirements in the NASA 1990 Solicitation differ from those in previous years. Proposals that do not meet all of the requirements of this Solicitation may not be evaluated. A check list is provided as Appendix D.

3. INFORMATION REQUESTS MUST BE LIMITED DURING SOLICITATION PERIOD

To insure competitive fairness to all, inquiries for interpretations of the intent or content of technical subtopics or for advice on the approach to or content of specific proposals cannot be accepted by NASA Field Installations or Headquarters Offices during the Phase I solicitation and proposal evaluation periods.

4. THERE ARE CONSTRAINTS ON SUBMITTING PROPRIETARY INFORMATION

Proprietary information must not be included in the Technical Objectives and Work Plan Sections of proposals. Provisions for including proprietary information in SBIR proposals are described in Section 5.4 of this Solicitation.

5. MANDATORY ELIGIBILITY REQUIREMENTS APPLY

Eligibility requirements for small businesses and Principal Investigators are given in Section 1.4.

6. NEW EMPHASIS IS PLACED ON PHASE III POTENTIAL

"Increasing private sector commercialization of innovations derived from Federal research and development" is one of the objectives stated in the SBIR legislation. NASA requires SBIR offerors to indicate whether or how their proposed project results may lead directly or indirectly to commercial applications. This information is taken into consideration during proposal evaluations and selections for award negotiations.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
1990 PROGRAM SOLICITATION
SMALL BUSINESS INNOVATION RESEARCH

1.0 PROGRAM DESCRIPTION

1.1 Summary

The National Aeronautics and Space Administration (NASA) invites small business firms to submit Phase I proposals under its Small Business Innovation Research (SBIR) Program Solicitation 90-1. Firms with research or research and development capabilities in science or engineering in any of the areas listed are encouraged to participate.

This, the eighth annual SBIR solicitation by NASA, describes the program, identifies eligibility requirements, outlines the required proposal format and content, states proposal preparation and submission requirements, describes the proposal evaluation and award selection process, and provides other information to assist those interested in participating in NASA's SBIR program. It also identifies, in Section 8.0 and Appendix E, the technical topics and subtopics in which SBIR Phase I proposals are solicited in 1990. These topics and subtopics cover a broad range of current NASA interests, but do not necessarily include all areas in which NASA plans or currently conducts research. High-risk, high pay-off innovations are desired.

For planning purposes, NASA expects to select approximately 275 high quality research or research and development (R/R&D) proposals for Phase I contract awards based on this Solicitation. Phase I contracts are for six months duration and may be funded up to $50,000, including profit. Selections will be based on the competitive merits of the offering and on NASA needs and priorities.

For planning purposes, NASA anticipates that approximately 50 percent of the Phase I projects - those deemed to have the highest feasibility and greatest value to NASA - will be selected competitively for further development under Phase II continuations. The Phase II period of performance and funding will depend on the project scope, but will normally not exceed 24 months and $500,000. Phase II competition is limited to Phase I contractors.

1.2 Program Features

Legislative Basis. The Small Business Innovation Development Act of 1982, 15 U.S.C. 638, P.L. 97-219 was enacted July 22, 1982 and was reauthorized by P.L. 99-443 on October 6, 1986. SBIR Program Guidelines are provided by the Small Business Administration Policy Directive for SBIR whose current revision became effective on June 28, 1988.

Objectives. SBIR program objectives include stimulating technological innovation in the private sector, strengthening the role of small business in meeting Federal research and development needs, increasing the commercial application of Federally supported research results, and fostering and encouraging participation by minority and disadvantaged persons in technological innovation.

Program Conduct. Participating agencies conduct SBIR programs by reserving 1.25 percent of their extramural research and development budgets for funding agreements with small business concerns for R/R&D during the first two phases of the three-phase process described below. Each agency, at its sole discretion, selects the technical topics and subtopics included in its Solicitation, chooses its SBIR awardees, and may decide to make several awards or no awards under any subtopic.

Funding Agreements. The funding agreements used by NASA in both Phase I and Phase II programs are contracts rather than grants or cooperative agreements. All contract awards are subject to the availability of Federal government funds.

1.3 Three-Phase SBIR Program

Phase I. Project objectives in Phase I are to establish the feasibility and merit of an innovative scientific or technical concept proposed in response to an opportunity or agency need stated in a subtopic of this

Solicitation. Projects may be experimental or theoretical in nature. Concepts proposed must be useful to NASA and should also suggest either direct or indirect commercial applications of end results (potential Phase III pursuits).

To reduce the time and cost for small firms in preparing a responsive proposal under this Solicitation, **the entire Phase I proposal is limited to 25 8½ x 11 inch pages, including all forms and any attachments or enclosures.**

The proposal should concentrate on means to establish or demonstrate the scientific or technical feasibility of the proposed innovation to justify further NASA support in Phase II.

Evaluation and selection criteria, which are described in Section 4.1 of this Solicitation, concentrate on technical merit and innovativeness, value to NASA and to the economy, and the ability of the proposer to conduct the research.

Phase I funding agreements with NASA are fixed-price contract awards. Simplified contract documentation is employed. Price competition is not usually a factor in Phase I within the $50,000 funding limitation, since the basis of selection among the best proposals will be value to the government in terms of the stated evaluation criteria and NASA priorities. NASA alone is responsible for those determinations.

Successful offerors will have up to six months to complete their Phase I research and an additional 30 days in which to submit their Phase I final reports. Phase I contractors competing for Phase II must meet the Phase II proposal schedule provided by the NASA Installation requesting their Phase II proposals. The Phase I final report is required to accompany the Phase II proposal because of its importance in Phase II evaluations.

Phase II. This SBIR phase is the principal research effort. Its purpose is to continue the development of the most promising innovations among the Phase I projects in an effort to achieve results most useful to NASA at their completion and which, it is hoped, may have even more far reaching values to the economy. Competition for Phase II continuations is limited to Phase I performers satisfactorily completing Phase I projects who meet all SBIR eligibility requirements and from whom NASA Installations have requested Phase II proposals. Phase II awards are expected to be made during 1991 to continue projects whose Phase I results suggest highest technical feasibility, merit, and NASA priority. Phase II award funding may be for as much as $500,000. Phase II periods of performance do not usually exceed 24 months.

Phase II proposals are more comprehensive than those required for Phase I and are not page-limited. They are prepared in accordance with instructions provided by the contracting NASA Field Installations after the Phase I contracts are awarded.

Selection criteria for Phase II awards are similar to those for Phase I and are described in Section 4.2 of this Solicitation. They in addition include evaluations of the results of the Phase I project and contractor performance. Proposed Phase II cost is an unscored selection factor based on NASA's judgments of cost-value and reasonableness. Selections also depend on NASA program priorities and availability of funds.

Among Phase II proposals determined to be suitable for award and to have essentially equal merit, NASA will give special consideration to those which have obtained valid non-Federal funding commitments for Phase III activities. The Phase III commitment is described in Section 4.2-c of this Solicitation.

Phase III. This activity consists of (1) the privately financed pursuit of commercial applications of the results of SBIR Phase I and Phase II research, or (2) continued Federal Government support of the research or acquisition of end products for government use, or a combination of (1) and (2) where appropriate. SBIR set-aside funds will not be used to support Phase III activities. Offerors are encouraged to seek non-Federal funding commitments (see Solicitation Section 4.2.c) and to secure them prior to NASA's completion of Phase II proposal evaluations, since such commitments can be key considerations in Phase II selections for award. Further details on Phase III commitments will be provided to those selected for Phase I awards.

1.4 Eligibility To Participate In SBIR

Small Business. Only firms qualifying as small businesses as defined in Section 2.2 of this Solicitation are eligible to participate in the SBIR program. SBIR eligibility does not require that the offeror qualify as a minority and disadvantaged small business (see Section 2.3) or as a women-owned small business (see Section 2.4).

Place of Performance. For both Phase I and II, the R/R&D must be performed in the United States (see Section 2.5), unless specifically approved otherwise by NASA.

Principal Investigator. The Principal Investigator (PI) is always presumed to be key to the success of an SBIR project. Due to the central role of the PI in a project, Co-Principal Investigators are not acceptable to NASA. The PI must possess the requisite technical competence and authority to plan and guide the proposed research, must make a substantial contribution to its conduct if the project is selected for award and in fact perform the activities specified and provide the time committed in the proposal for that effort. After an award is made, any substitution for an approved Principal Investigator may be made only with NASA's consent.

The primary employment of the principal investigator must be with the small business firm at the time of contract award and during the conduct of the proposed research. Primary employment means that more than one-half of the principal investigator's time is spent in the employ of the small business. Primary employment with the small business precludes full-time employment or full-time student status in an academic institution during the conduct of the SBIR project. If a principal investigator is employed by an academic institution in a tenured position or on a tenure track, he or she is considered a full-time employee of that institution regardless of consulting, part-time or summer employment. Leaves of absence, sabbaticals, or other release time from an academic institution will not influence the determination of primary employment status unless the periods of such release are for the full Phase I and Phase II periods of performance.

If the primary employment of a principal investigator is not clear, NASA may require verification by the current employing institution before a proposal is accepted for evaluation and/or before an award is made. Should appropriate verification not be provided, such a proposal would be considered nonresponsive to this solicitation and would be returned to the proposer without evaluation or award.

1.5 General Information

Relevance of the Proposed Innovation. Each proposal must be based on an innovative, original concept relevant to meeting a NASA program need or opportunity identified in a subtopic listed in Appendix E of this Solicitation, and it may be submitted under only one subtopic (see Section 5.14-d). Proposals must conform to the format and requirements described in Section 3 of this Solicitation.

Questions about this Solicitation. For competitive fairness to all offerors, all communications regarding this Solicitation during the Phase I proposal preparation period are restricted to requests for clarification of solicitation instructions. Inquiries must be submitted in writing to the address below:

Mr. John A. Glaab
SBIR Program Manager
Code CR
National Aeronautics and
Space Administration
Washington, DC 20546

Attn: 90-1 Question

Additional Copies of this Solicitation or of Appendix A and B forms may be ordered by writing the SBIR Program Manager at the address listed above. Telephone requests will not be accepted.

Questions Regarding Proposal Status. Evaluation and selection of proposals for contract award will require approximately three months. No information on proposal status will be available until the final selections are announced, except for NASA's postal confirmation of receipt of proposal as noted in Section 6.5 of this Solicitation.

General Questions about the SBIR Program. Questions about NASA's SBIR Program which do not pertain to this Solicitation or requests for copies of the Solicitation may be submitted in writing to either Harry W. Johnson, SBIR Director, or John A. Glaab, SBIR Program Manager, at the above address or the offeror may call the SBIR

Program Inquiry telephone number, 202-453-2649, giving (1) company name; (2) full 1990 proposal number (example: NASA 90-1-04.06-9876A); (3) company address and telephone number; (4) whom to contact; (5) date and time the call placed to NASA; and (6) the specific inquiry.

Scientific and Technical Information. Information sources on NASA R/R&D programs include NASA Industrial Application Centers and the National Technical Information Service. Their addresses are included in Section 7.0 of this Solicitation. **NASA assumes no responsibility for any information these organizations may provide as interpretations of the content or intent of technical subtopics in this Solicitation, or for their assistance to offerors on proposals.**

2.0 DEFINITIONS

The following definitions apply for purposes of this Solicitation:

2.1 Research or Research and Development (R/R&D) - Any activity that is (1) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied, (2) a systematic study directed specifically toward applying new knowledge to meet a recognized need, or (3) a systematic application of knowledge toward the production of useful materials, devices, and systems or methods, including the design, development, and improvement of prototypes and new processes to meet specific requirements.

2.2 Small Business - A concern that, at the time of award of Phase I and Phase II -

- Is independently owned and operated, is organized for profit, is not dominant in the field of operation in which it is proposing, and has its principal place of business located in the United States;
- Is at least 51 percent owned, or, in the case of a publicly owned business, at least 51 percent of its voting stock is owned by United States citizens or lawfully admitted permanent resident aliens; and
- Has, including its affiliates, a number of employees not exceeding 500 and meets the other regulatory requirements found in 13 CFR Part 121. Business concerns, other than investment companies licensed, or state development companies qualifying under the Small Business Investment Act of 1958, 15 U.S.C. 661, et seq., are affiliates of one another when, either directly or indirectly, (1) one concern controls or has the power to control the other or (2) a third party controls or has the power to control both. Control can be exercised through common ownership, common management, and contractual relationships. The term "affiliates" is defined in greater detail in 13 CFR 121.3(a). The term "number of employees" is defined in 13 CFR 121.2(b). Business concerns include, but are not limited to, a sole proprietorship, partnership, corporation, joint venture, association or cooperative.

2.3 Minority and Disadvantaged Small Business Concern - A small business concern that (1) is at least 51 percent owned by one or more individuals who are both socially and economically disadvantaged, or a publicly owned business having at least 51 percent of its stock owned by one or more socially and economically disadvantaged individuals, and (2) has its management and daily business controlled by one or more such individuals.

Minority and disadvantaged individuals include members of any of the following groups: Black Americans; Hispanic Americans; Native Americans (American Indians, Eskimos, Aleuts, and native Hawaiians); Asian-Pacific Americans; and subcontinent Asian Americans.

2.4 Women-Owned Small Business - A small business that is at least 51 percent owned by a woman or women who also control and operate it. To "control", in this context, means to exercise the power to make policy decisions. To "operate", in this context, means to be actively involved in day-to-day management.

2.5 United States - The 50 states, the District of Columbia, the Territories and possessions of the United States, the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana

Islands, and the Trust Territory of the Pacific Islands.

2.6 Subcontract – Any agreement, other than one involving an employer-employee relationship, entered into by a Federal Government contractor calling for supplies or services required solely for the performance of the original contract. See also Sections 3.3.D-9 and 5.12 of this Solicitation.

2.7 Innovation Research – R/R&D on an innovation. Innovation in the context of the NASA SBIR program includes, but is not limited to, invention. Innovation encompasses new, original and imaginative approaches to the solution of new and old problems, evolutionary and revolutionary improvements or advances to existing technology, exploitation of new technological opportunities, and some limited aspects of basic research when such objectives are stated in the technical subtopics.

Proposals for surveys, general or specific studies, and conventional applications of engineering design, development or testing of products which do not require innovation as defined above will not be evaluated in the SBIR program. NASA would expect to procure such activities and products through other means.

3.0 PHASE I PROPOSAL CONTENT AND PREPARATION

3.1 Proposal Objectives and Considerations

The purpose of a Phase I proposal under the SBIR Program is to provide sufficient information to persuade NASA that the proposed work represents a sound approach to the investigation of an important scientific or engineering innovation of interest to NASA and is worthy of support under the stated selection criteria. A proposal should be self-contained and written with the care and thoroughness accorded papers for publication.

Important considerations include the following:

- SBIR proposals must be limited to activities requiring significant scientific or technical innovation R/R&D, either experimental or theoretical. They may or may not involve construction and evaluation of a laboratory prototype, but **each project must develop specific end products or results** for delivery at the conclusion of the project which may include data, reports, hardware and software programs.

- Scientific or technical merit of the proposed innovation and its value to the NASA program are primary factors without which no award would be made.

- An SBIR proposal may respond to only one of the subtopics in Appendix E, (see Section 5.14-d) and must address a NASA program objective or opportunity described therein. Ideally, the proposed innovation should also serve as the basis, directly or indirectly, for new commercial products, processes, or services which may benefit the general economy.
- Proposals directed toward market research or the commercial development of existing products or concepts - unproven, proven, proprietary, patented or otherwise – should not be submitted for SBIR support. Such activities are considered responsibilities of the private sector and may not be funded by SBIR.

3.2 General Requirements

Page Limitation. A Phase I SBIR proposal shall not exceed a total of 25 standard 8-1/2" x 11" pages consisting of the cover page (Appendix A form in this Solicitation), project summary (Appendix B form in this Solicitation), the technical proposal, the proposed budget (Appendix C form in this Solicitation), and any enclosures, attachments or addendum the offeror provides. Each page shall be numbered consecutively at the center, bottom. All material supplied, except the check list (Appendix D in this Solicition) will be included in the page count. **Proposals exceeding the 25 page limitation will be returned without consideration.**

Type Size. No type size smaller than elite is to be used for text or tables, except as legends on reduced drawings. Pages are to be printed on one side only, and may be single or double spaced.

Brevity Is Desired. The proposal should be direct, concise, and informative. Promotional and non-project-related material should not be included. **Offerors are requested not to use the entire 25 page allowance unless that is actually necessary. Appropriate brevity facilitates proposal evaluations.**

Content and Format. All required items of information are to be covered fully and in the order set forth in Section 3.3 of this Solicitation, but the space allocated to each will depend on the project chosen and the Principal Investigator's approach.

NASA Use of Optical Character Readers. To facilitate proposal processing, NASA intends to employ optical character readers to record proposal cover sheet and project summary information wherever possible. Therefore it is required that the proposal cover sheet (Appendix A) and the project summary (Appendix B) be typed carefully on the indicated lines using one of the following type styles:

COURIER 12 10 or 12 PITCH
COURIER 72 10 PITCH
ELITE 72
LETTER GOTHIC 10 or 12 PITCH
OCR-B 10 or 12 PITCH
PICA 72 10 PITCH
PRESTIGE ELITE 10 or 12 PITCH
PRESTIGE PICA 10 PITCH

IMPORTANT: Do Not Use Proportional Spacing on Appendixes A and B

Check List. The Check List (Appendix D in this Solicitation) is provided to assist the offeror. One copy of Appendix D is to be completed and included with the original signed copies of Appendixes A and B as noted in Section 6.1 of this Solicitation. The Check List is not counted as a proposal page.

3.3 Required Phase I Proposal Format

The format required for all Phase I proposals is provided herewith. **Proposals will consist of Parts A, B, C, D and E** below, but may also include supplementary information (included in the total page count) at the option of the offeror. **Part D** is further subdivided into eleven numbered Sections. **All proposal Parts and Sections must be addressed, and must follow in order.**

Part A. Cover Sheet. The offeror shall include a photocopy of the signed original cover sheet (Appendix A in this Solicitation) as page 1 of each copy of the proposal. No other cover sheet is permitted. The proposal title must be concise and descriptive, but must not be stated as an acronym.

Part B. Project Summary. The offeror shall include a photocopy of the signed original project summary (Appendix B in this Solicitation) as page 2 of each copy of the proposal. The technical abstract section should include (1) a brief description of the **proposed innovation** and how it addresses the stated subtopic problem or opportunity, (2) the project objectives, and (3) a description of the effort proposed and results anticipated. In summarizing anticipated results, the expected NASA applications and benefits and any potential commercial applications shall be identified. **The project summary of successful proposals will be published by NASA, therefore ALL information provided on Appendix B of all proposals will be treated by NASA as non-proprietary information.**

Part C. Table of Contents. Page 3 of the proposal shall begin with a brief table of contents indicating the presence and page numbers of each of the parts and sections of the proposal.

NOTE: Detailed instructions for completing Appendixes A, B and C are printed on their reverse sides.

Part D. Technical Proposal. The Technical Proposal shall consist of the following **eleven sections. Entries are required in each section.**

Sect. 1. Identification and Significance of the Innovation. The first paragraph shall contain a clear and succinct statement of **the specific innovation** proposed, why it is an innovation, and how it is relevant and important to meeting the need or opportunity described in the subtopic. The paragraph shall contain no more than 150 words. **NASA reserves the right to refuse proposals which lack this introductory paragraph.**

This section of the proposal may also include appropriate background and elaboration to explain the proposed innovation and its value to NASA.

Sect. 2. Phase I Technical Objectives. This section shall include the specific objectives of the Phase I effort and state the technical questions the offeror will try to answer to determine the feasibility of the proposed innovation.

Sect. 3. Phase I Work Plan. This section should be comprehensive and explanatory, normally constituting approximately one-third of the total proposal. It shall include a detailed description of the proposed Phase I activities indicating what will be done and where the work will be carried out. The methods planned to achieve each objective or task should be discussed in detail. Schedules (Gantt Charts or other suitable scheduled task displays), task descriptions and assignments, resource allocations and planned accomplishments including project milestones shall be included.

The Phase I Work Plan must be complete and self-contained. However, Section 5.4-a of this Solicitation gives instructions for including proprietary information in an SBIR proposal as a separate "Proprietary Addendum," and what must be done to protect such information from public disclosure. Offerors are advised to avoid including proprietary information if at all possible.

Sect. 4. Related R/R&D and Bibliography of Related Work. The purpose of this section is to make clear the offeror's awareness of key recent developments by others in the specific subject area. It should include any significant R/R&D directly related to the proposal that was conducted by the Principal Investigator or by the offeror's firm. Any planned coordination with outside sources during the course of the proposed research should also be stated.

At the offeror's option, this section may include concise bibliographic references in support of the proposal if they are confined to activities directly related to the proposed work.

Sect. 5. Relationship with Phase II or other Future R/R&D. This section shall explain why the expected Phase I results should warrant Phase II continuation, state the anticipated Phase II objectives, and include the offeror's suggested applications by NASA. Any other planned R/R&D related to the proposed research should also be noted.

Sect. 6. Potential Commercial Applications. Commercialization of the results of research innovations supported by Federal R&D is an important SBIR goal. Offerors shall discuss whether the results or products of their proposed innovation research have potential direct or indirect commercial applications, and include their intentions (and plans, if any) to pursue commercialization in Phase III if the research effort through Phase II is successful.

Sect. 7. Company Information. This section will provide information needed by evaluators to assess the ability of the firm to carry out the proposed Phase I and projected Phase II activities. While extensive background or experience is not a prerequisite for an SBIR award, the ability of the offeror to perform the proposed activities must be established before an award is made.

A description of the firm's business organization, operations, R/R&D capabilities and experience is to be provided if it has such a history. All firms, including start-up firms are requested to outline their business objectives or plans in which this SBIR project would fit.

This section must also provide a description of the firm's physical facilities including any instrumentation and equipment pertinent to the proposed research. If facilities, equipment and instrumentation needed for the proposed research are not presently available, the offeror must explain how they are to be obtained.

As a general rule, NASA will not fund the purchase of equipment or instrumentation (or acquisition of facilities) under SBIR Phase I contracts. If such purchases are authorized, title will vest in the U.S. government. Refer also to Part E, below.

Sect. 8. Key Company Personnel. This Section shall identify the key company employees to be committed to Phase I activities, including the Principal Investigator and other individuals whose expertise is essential to the success of the research. Information on their education

and experience, and directly related bibliographic information is required. Offerors are requested to avoid extensive vitae and publication lists not pertinent to the proposed research.

This section shall also establish the Principal Investigator's eligibility (see Section 1.4 of this Solicitation) and indicate the extent to which (1) other proposals recently submitted or planned to be submitted in 1990, and (2) existing projects for which he/she is identified as PI would commit his/her time concurrently with this proposed activity.

Sect. 9. Subcontracts and Consultants. Up to one-third of the research and/or analytical effort in Phase I may be conducted under subcontract to other firms, nonprofit organizations and individual consultants (see Section 5.12 of this Solicitation). Subcontracting is encouraged when it permits the firm to write a better proposal, conduct more valuable research, and improve its prospects for commercial success.

This section must describe any subcontracting requirements and identify the organizations and individuals with whom subcontracts are planned. Generally, these arrangements will be viewed as key to the success of the work, so the expertise to be subcontracted must be described in detail as well as the functions, services, time intervals and extent of effort to be provided.

The proposal must include an agreement by each subcontracting organization and individual consultant that they will be available at the times required for the purposes and extent of effort described in the proposal.

Sect. 10. Related Proposals to and Awards from Other Agencies. If the offeror (a) has received Federal government awards for related work, or (b) has submitted proposals for essentially equivalent or similar work under other Federal government program solicitations, or (c) intends to submit proposals for such work to other agencies during 1990, those awards, proposals and intentions shall be identified. A statement must be included indicating:

(1) The agencies to which proposals were submitted or from which awards were received.

(2) Date of proposal submission or date of award.

(3) Solicitation numbers under which proposals were submitted or awards received.

(4) The specific research topic for each proposal submitted or awards received.

(5) Titles of research projects.

(6) Name and title of principal investigator for each proposal submitted or award received.

(7) Intended proposal submissions in 1990.

NOTE: If no such awards have been received, or proposals submitted or intended, the offeror shall so state.

Sect. 11. Previous NASA SBIR Awards Received. Offerors who have received previous NASA SBIR awards shall provide a list including contract numbers and titles, indicating the year of award and the NASA installation making the award. If no NASA awards have been received, the offeror shall so state.

Part E. Proposed Budget. Offerors shall complete Appendix C, SBIR Summary Budget, and include it (and any budget explanation sheets if needed) as the last page(s) of the proposal. Items on Appendix C that do not apply to the proposed project may be omitted. What matters is that enough information be available to allow NASA to understand how the offeror plans to use the requested funds and business-like evidence that the proposed budget is realistic and cost-effective. Special attention is directed to the following items:

Title to All Property. Because NASA will not normally fund instrumentation, equipment or facility acquisition under Phase I, the inclusion of such items should be avoided if possible and must be fully justified if included. Any inclusion of such items will be carefully reviewed relative to need and appropriateness for the research proposed.

Equipment is defined as an article of non-expendable, tangible, personal property having a useful life of more than one year and an acquisition cost of $1,000 or more per unit. Title to all property (including equipment) acquired under an SBIR contract will be vested in NASA unless it is determined that transfer of title to the contractor would be more cost effective than recovery of the property by NASA.

It should be noted that prototypes, working models and devices, measurement instrumentation and test apparatus built under NASA SBIR contracts and which cost more than $1000 per unit to develop are normally considered to be equipment owned by and deliverable to NASA. Proposals should clarify the Offeror's expectations or plans, if any, for future use and possible ownership of such items to avoid possible future misunderstandings.

Travel. Budgets for travel funds are not normally acceptable, but if proposed must be justified as essential to the conduct of the project.

Profit. A profit or fee may be included in the proposed budget as noted in Solicitation Section 5.9.

4.0 PROPOSAL EVALUATION AND AWARD SELECTION

4.1 Phase I

a. Evaluation and Selection. The initial step is screening for compliance with administrative requirements of the Solicitation. Proposals which pass that screening are then reviewed to determine whether they respond to the subtopic chosen by the offeror. Those found to be responsive are evaluated in greater depth by two or more scientists and engineers at the NASA Installation responsible for the research, using the criteria listed below.

Evaluators base their conclusions only on information contained in the proposal. Offerors should not assume that evaluators are acquainted with the firm or key individuals or with any experiments or other information referred to but not described in referenced professional journals. To be of any value in this process, relevant information must be identified in Part D-4 of the proposal.

Each proposal is judged and scored on its own merits using an established uniform scoring procedure, then is ranked relative to all others evaluated under the same subtopic. Those considered suitable for selection are recommended for further consideration by the NASA Installation SBIR Committee, which prepares final recommendations for selection in priority order, based on proposal merit, program balance and Installation needs. These recommendations are then forwarded to NASA Headquarters for final selection decisions which take into consideration the recommendations from all Installations and overall NASA priorities and program balance. Proposals judged to have the highest merit and value to NASA will be selected for negotiations that may lead to contract awards.

Proposals are evaluated at the NASA Installation cited in the Solicitation subtopic, but other NASA Installations may also conduct evaluations and make recommendations for selections of any proposals received by NASA from this Solicitation.

In the evaluation and handling of proposals, NASA will make every effort to protect the confidentiality of the proposals and their evaluations.

b. Phase I Evaluation Criteria. NASA plans to select proposals which offer the best value to the Government, giving approximately equal consideration to each of the following four criteria except for the first, which has twice the weight of each other item:

1. **Scientific/technical merit** of (a) the proposed innovation and its relevance to the needs stated in the selected subtopic, and (b) the proposal's statement of objectives and approach for addressing questions of feasibility. Special emphasis is placed on innovativeness and originality.

2. **Qualifications** of the principal investigator, other key staff, consultants and subcontractors, if any, and the adequacy of available or obtainable instrumentation and facilities.

3. Anticipated benefits (technical and/or economic) to the NASA mission through applications subsequent to Phase II, and the potential for direct or derived commercial applications of the expected results or products if the research is successful.

4. Soundness and technical merit of the proposed work plan including its likelihood of meeting the Phase I objective of establishing the feasibility and merit of the proposed innovation as a basis for Phase II continuation.

4.2 Phase II

During the course of Phase I, the NASA Installations awarding SBIR Phase I contracts will issue requests for Phase II proposals to those contractors whose progress is deemed to be satisfactory, if NASA is interested in Phase II continuations. A Phase II proposal may be submitted only by the firm performing the Phase I research. Information provided by NASA will include instructions regarding Phase II proposal submission, the relative importance of the evaluation factors to be employed, the date when Phase II proposals must be submitted (usually, one month after the end of the Phase I performance period), and other information to facilitate their compliance with Phase II requirements.

a. Evaluation and Selection. Phase II proposals undergo a technical review and competitive selection process in greater depth than Phase I proposals. As in Phase I, the Phase II proposals are evaluated by the NASA Installations responsible for the research using uniform evaluation procedures and the criteria noted below. Proposals are then ranked by the Installation SBIR Committee taking into consideration overall quality, value to NASA, and Installation program balance. Recommendations are forwarded to NASA Headquarters for final consideration with the recommendations made by all Installations.

Final selections take into consideration overall NASA programmatic or schedule requirements and availability of funds. Special consideration is given to acceptable proposals of essentially equivalent merit for which valid non-Federal funding commitments for Phase III activities have been obtained (refer to Section 4.2.c of this Solicitation).

At its discretion NASA may initiate early negotiations for a Phase II award at any time after the proposal has been received.

b. Phase II Evaluation Criteria. Evaluation criteria for Phase II proposals include:

1. Scientific/technical merit and feasibility of the proposed R&D, with special emphasis on its innovativeness, originality and technical payoff potential if successful.

2. Results of Phase I, including feasibility of the innovation and how well the results support current NASA program priorities.

3. Future importance and eventual value of the product, process or technology results to the mission of NASA after completion of Phase II. The potential for commercial applications of the expected research results or products if the research is successful will also be considered.

4. Ability of the Small Firm. NASA will assess the ability of the firm to conduct Phase II based on (a) the validity of the project plans for achieving the stated goals, (b) the qualifications and ability of the project team (Principal Investigator, company staff, consultants and subcontractors) relative to the proposed research, and (c) the availability of any required equipment and facilities.

c. Non-Federal Commitments for Phase III Funding. Valid non-Federal capital commitments for Phase III follow-on activities may be contingent on the outcome of Phase II and on other stated circumstances, but must provide that a specific, substantial amount (usually at least half the Phase II funding request) will be made available to the firm to pursue Phase III and must indicate the source and date or conditions under which the funds will be made available. Realistic, substantial self-commitments by the firm can also qualify.

Valid commitments must be provided as brief letters to the proposing firms from the organization making the commitments. Preferably, they should accompany the Phase II proposal but they may be considered up until final Phase II award decisions have been made by NASA. It should be noted that mere

expressions of technical interest in the outcome of the Phase II research, or of potential future financial interest by a third party are not valid Phase III commitments and will not be accepted as such by NASA.

4.3 Debriefing of Unsuccessful Offerors

After final Phase I and Phase II award decisions have been announced, a critique (a debriefing) for an unsuccessful offeror may be provided – to the offeror only – upon written request. Telephone requests for debriefings will not be accepted. Debriefings are not opportunities to reopen selection decisions. They are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal and perhaps to provide suggestions for constructive future action by the offeror.

Debriefings will not disclose the identity of the proposal evaluators and NASA will provide the evaluators' actual comments in the course of debriefings only at its option. Such information is exempt from Freedom of Information disclosure, as are proposal scores, proposal rankings in the competition, and the content of and comparisons with other proposals with which they were in competition.

Phase I. For Phase I proposals, all requests for debriefing must be directed in writing to the SBIR Program Manager, NASA Headquarters, within 45 days after notification has been mailed to the offeror that its proposal was not selected for award. When feasible to do so, oral (telephone) debriefings will be provided; otherwise written debriefing comments will be mailed.

Phase II. To request debriefings on Phase II proposals, proposers must contact the SBIR Procurement Officer at the NASA Installation responsible for their Phase I contract.

5.0 CONSIDERATIONS

5.1 Awards

In October 1990, NASA expects to announce the selection of approximately 275 proposals for negotiation of fixed-price Phase I contracts with values ranging up to $50,000. Following contract negotiations and awards, Phase I contractors will usually have six months to carry out their proposed Phase I programs.

For planning purposes, NASA anticipates that during 1991 approximately 50 percent of the Phase I projects resulting from this Solicitation may be selected for Phase II continuations, based on the results of Phase I activities and competitive evaluations of Phase II proposals. Phase II funding agreements may be either fixed-price type or cost-type contracts. Phase II performance periods normally will not exceed 24 months with funding not exceeding $500,000.

Both Phase I and Phase II awards are subject to availability of funds. NASA has no obligation to make any specific number of Phase I or Phase II awards based on this Solicitation, and may elect to make several or no awards in any specific technical topic or subtopic.

5.2 Reports

Six (original plus five) copies of a final report on the Phase I project must be submitted to NASA within 30 days after completion of the Phase I research effort. The final report shall include a single page project summary as the first page, on a form to be provided by NASA for that purpose, identifying the purpose of the research, a brief description of the research carried out, the research findings or results including the degree to which the Phase I objectives were achieved, and whether the results justify Phase II continuation. The potential applications of the project results through Phase II both for NASA purposes and for commercial purposes will also be included. The project summary is to be submitted without restriction for NASA publication. The balance of the report shall elaborate the project objectives, work carried out, results obtained, and assessments of technical feasibility. Rights to this data shall be in accordance with the policies set forth in Section 5.5.

To avoid duplication of effort, language used in the Phase I report may be used verbatim in the Phase II proposal.

5.3 Payment Schedule

Payments on Phase I contracts may be invoiced as follows: one-third at the time of award, one-third at project mid-point after award, and the remainder upon acceptance of the final report by NASA. Payments will be made 30 days after receipt of valid invoices.

5.4 Treatment and Protection of Proposal Information

a. Proprietary Information. It is NASA policy to use information (data) included in proposals for evaluation purposes only and to protect such information from unauthorized use or disclosure. While this policy does not require that the proposal bear a notice, protection can be assured only to the extent that an appropriate "Notice", set forth in the clause of the NASA FAR Supplement at 18-52.215-72, Restriction on Use and Disclosure of Proposal and Quotation Information (Data), is applied to the data which constitute trade secrets or other information that is commercial or financial and confidential or privileged, as follows:

> "NOTICE: No proprietary information is included except in a Proprietary Addendum. The information (data) on pages ________ in the Proprietary Addendum Section of this proposal constitute a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, in the event a contract is awarded on this proposal, the Government may obtain additional rights to use and disclose this information (data)."

Other information will be afforded protection to the extent permitted by law, but NASA assumes no liability for use and disclosure of information to which the "Notice" has not been appropriately applied.

The offerer should also note that the above notice is printed on the proposal cover page to alert NASA to the presence of a "Proprietary Addendum" if one is included. **Proposals containing any other information marked as proprietary will not be evaluated.**

b. Non-NASA Reviewers. In addition to Government personnel, NASA, at its discretion and in accordance with 18-15.413-2 of the NASA FAR Supplement, may utilize scientists and engineers from outside the government in the proposal review process. Any decision to obtain outside evaluation shall take into consideration requirements for the avoidance of organizational or personal conflicts of interest and the competitive relationship, if any, between the prospective contractor or subcontractor(s) and the prospective outside evaluator. Any such evaluation will be under agreement with the evaluator that the information (data) contained in the proposal will be used only for evaluation purposes and will not be further disclosed.

c. Release of Proposal Information. By submission of a proposal, the offeror agrees to permit the government to disclose publicly the information contained in Appendixes A and B. Other proposal information (data) is considered to be the property of the offeror, and NASA will protect it from public disclosure to the extent permitted by law.

It is NASA's practice to notify the offeror of the proposal before releasing any information (data) contained therein pursuant to a request under the Freedom of Information Act (5 U.S.C. 552) and, time permitting, to consult with the offeror to obtain assistance in determining the eligibility of the information (data) in question as an exemption under the Act.

d. Final Disposition of Proposals. The government retains ownership of the copies of proposals accepted for evaluation and they will not be returned to the offeror.

Copies of all proposals evaluated will be retained until the Phase I selection awards have been made, after which time those which were not selected for award will be destroyed.

5.5 Rights in Data Developed Under SBIR Contracts

Rights to data used in, or first produced under, any Phase I or Phase II contract are specified in the clause at FAR 52.227-20, Rights in Data - SBIR Program. Such clause provides for rights consistent with the following:

a. Some data of a general nature are to be furnished to NASA without restriction

(i.e., with unlimited rights) and may be published by NASA. These data will normally be limited to the project summary accompanying any periodic progress reports and the final report required to be submitted (see Section 5.2) but, in any event, the requirement for them will be specifically set forth in any contract resulting from this solicitation.

b. In keeping with NASA's policy, data that constitute trade secrets or other information that is commercial or financial and confidential or privileged **and developed at private expense** will not normally be acquired, but if acquired will be with "limited rights" or "restricted rights." Such rights do not include the right to use the data for manufacturing or reprocurement purposes.

c. Other than as required by (a) above, rights in technical data including software developed under the terms of any funding agreement resulting from proposals submitted in response to this Solicitation shall remain with the contractor, except that the government shall have the limited right to use such data for government purposes and shall not release such data outside the government without permission of the contractor for a period of two years from completion of the project from which the data were generated, i.e., after completion of Phase II if the Phase I project receives Phase II funding. However, effective at the conclusion of the two year period, the government shall retain a royalty-free license for government use of any technical data delivered under an SBIR contract whether patented or not, but (except per (b) above) is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of the data by third parties.

5.6 Copyrights

Contractors will be permitted (in accordance with paragraph (c) of the clause at FAR 52.227-20) to assert or establish claim to copyright data first produced under a Phase I or Phase II contract, subject to a paid-up, non-exclusive, irrevocable, worldwide license for governmental purposes. The contractor is required to include an appropriate credit line acknowledging government support for any works published under copyrights.

5.7 Patents

The contractor will, as provided in the clause at FAR 52.227-11, Patent Rights - Retention by Contractor (Short Form), have first option to retain title to inventions made in the performance of any Phase I or Phase II contract in accordance with P.L. 96-517 (35 U.S.C. 200, et. seq.). This option is subject to the reservations and limitations, including a nonexclusive, royalty-free, irrevocable license in the Government and certain march-in rights to assure commercialization, as required by 35 U.S.C. 203 and implementing regulations thereunder.

Whenever an invention is made and reported under any NASA contract, it is NASA policy to withhold such report from disclosure to the public and to use reasonable efforts to withhold other information which may disclose the invention (provided that NASA is notified of the information and the invention to which it relates) for a reasonable time to allow the contractor to obtain patent protection as authorized by 35 U.S.C. 205.

5.8 Cost Sharing

Cost sharing is permitted for proposals under this Program Solicitation. However, cost sharing is not required, nor will it be a factor in proposal evaluation. NASA limits the Phase I award amount to $50,000.

5.9 Profit or Fee

Both Phase I and Phase II SBIR contracts may include a reasonable profit or fee.

5.10 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as a small business in accordance with the definition in Section 2.2.

5.11 Similar Proposals and Prior Work

Submission of related proposals to and receipt of related awards from other agencies, intentions to submit related proposals during to 1990 to other agencies, and prior NASA SBIR awards received by the offeror must be identified in the Technical Proposal Sections D-10 and D-11 as noted in Section 3.3 of this Solicitation.

If an award is made pursuant to a proposal submitted under this Program Solicitation, the firm will be required to certify that it has not previously been, nor is currently being, paid for essentially equivalent work by any agency of the Federal government.

5.12 Limits on Subcontracting Research and Analytical Work

Subcontracts (defined in Section 2.6 of this Solicitation) may be placed with other firms, universities and other non-profit organizations, and with individual consultants, but there are cost limits on subcontracting the research and analytical portions of both Phase I and Phase II contracts:

- For Phase I, a minimum of two-thirds of the research and/or analytical effort must be performed by the proposing firm unless otherwise approved in writing by the contracting officer.
- For Phase II, a minimum of one-half of the research and/or analytical effort must be performed by the proposing firm unless approved in writing by the contracting officer.

NOTE: The costs of research and analytical effort do not include the SBIR contractor's costs for overhead, general and administrative costs, and profit or fee.

5.13 Contractor Commitments

Upon award of a contract, the contractor will be required to make certain legal commitments through acceptance of numerous clauses in the Phase I contract. The outline that follows illustrates the types of clauses that will be included in the Phase I contract. This is not a complete list of clauses to be included in Phase I contracts, nor does it contain specific wording of these clauses. Copies of complete general provisions will be made available prior to award.

a. Standards of Work. Work performed under the contract must conform to high professional standards. Analyses, equipment, and components for use by NASA will require special consideration to satisfy the stringent safety and reliability requirements imposed in aerospace applications.

b. Inspection. Work performed under the contract is subject to government inspection and evaluation at all reasonable times.

c. Examination of Records. The Comptroller General (or a duly authorized representative) shall have the right to examine any directly pertinent records of the contractor involving transactions related to the contract.

d. Default. The government may terminate the contract if the contractor fails to perform the contracted work.

e. Termination for Convenience. The contract may be terminated at any time by the government if it deems termination to be in its best interest, in which case the contractor will be compensated for work performed and for reasonable termination costs.

f. Disputes. Any dispute concerning the contract that cannot be resolved by mutual agreement shall be decided by the contracting officer with right of appeal.

g. Contract Work Hours. The contractor may not require an employee to work more than 40 hours a week unless the employee is compensated accordingly (that is, receives overtime pay).

h. Equal Opportunity. The contractor will not discriminate against any employee or applicant for employment because of race, color, religion, sex or national origin.

i. Affirmative Action for Veterans. The contractor will not discriminate against any employee or applicant for employment because he or she is a disabled veteran or veteran of the Vietnam era.

j. Affirmative Action for Handicapped. The contractor will not discriminate against any employee or applicant for employment because he or she is physically or mentally handicapped.

k. Officials Not to Benefit. No member of or delegate to Congress shall benefit from the contract.

l. Covenant Against Contingent Fees. No person or agency has been employed to solicit or secure the contract upon an understanding for compensation except bona fide employees or commercial agencies maintained by the

contractor for the purpose of securing business.

m. Gratuities. The contract may be terminated by the government if any gratuities have been offered to any representative of the government to secure the contract.

n. Patent Infringement. The contractor shall report to NASA each notice or claim of patent infringement based on the performance of the contract.

5.14 Additional Information

a. Precedence of Contract over Solicitation. This Program Solicitation is intended for informational purposes and reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR contract, the terms of the contract are controlling.

b. Evidence of Contractor Responsibility. Before award of an SBIR contract, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to establish responsibility of the offeror.

c. Limitations on Awards. This Solicitation is not an offer by the Government to make any specific number of awards under either Phase I or Phase II. NASA is not responsible for any monies expended by the offeror before award of any contract resulting from this Solicitation. Also, awards under this Program Solicitation 90-1 are contingent upon the availability of funds.

d. Multiple Proposal Submissions. An offeror may submit any number of different Phase I proposals on different subtopics, or different proposals on the same subtopic. However, every proposal must be limited in scope to one subtopic. Should the offeror consider a proposal to have relevance to more than one subtopic, the offeror must choose the one under which to submit the proposal. Neither an identical proposal nor substantially similar proposals may be submitted to the other subtopics. Within the submitted proposal, the discussion of the innovation may identify other subtopics for which the concept is believed relevant; **however, such identification will not insure that the proposal will be evaluated within any subtopic other than the one to which the proposal is addressed, or at NASA Installations other than those identified in the subtopic addressed.**

Offerors should be aware that none of any identical or substantially similar proposals submitted in response to this Solicitation, whether to one or to several subtopics, will be evaluated.

e. Classified Proposals. NASA will not accept classified proposals.

f. Unsolicited Proposals. Unsolicited proposals will not be accepted under the SBIR program in either Phase I or Phase II.

6.0 SUBMISSION OF PROPOSALS

6.1 What to Send

Offerors must submit the following items for each proposal:

a. One Original Proposal Cover as a separate sheet. This is Appendix A, a red-printed form included in this Solicitation.

b. One Original Project Summary as a separate sheet. This is Appendix B, a red-printed form included in this Solicitation.

c. One Check List as a separate sheet. This is Appendix D, a black-printed form included in this Solicitation.

NOTE: DO NOT STAPLE ITEMS (a), (b) and (c) TOGETHER: LEAVE SEPARATE.

d. Five black and white copies of the entire proposal, complete with copies of Appendices A, B and C (but excluding Appendix D) and any optional enclosures, attachments and addenda. Each proposal copy is to be stapled separately. All pages are included in the page count, which is limited to 25 standard 8-1/2" x 11" pages.

6.2 Physical Packaging Requirements

Bindings. Do not use bindings or special covers. Staple the pages of each copy of the proposal **only** in the upper left-hand corner.

Packaging. All items (6.1 a through d) for **any proposal must be sent in the same package.** If more than one proposal is being submitted, it is requested that all proposals be sent in the same package whenever possible.

NOTE: DO NOT SEND ADDITIONAL SETS of any proposal as "insurance" that they will be received.

6.3 Where to Send Proposals

Proposals shall be addressed as below:

SBIR Program Manager
Code CR
National Aeronautics and
Space Administration
Washington, DC 20546

Note: No street address is required

Handcarried proposals or proposals delivered by messenger should be delivered to the NASA Headquarters Mailroom, which address is Room A16, Federal Office Building 10B, NASA Headquarters, 600 Independence Avenue, SW, Washington, DC, 20546. Secure packaging is mandatory. NASA cannot process proposals damaged in transit.

NOTE: 1. Deliver packages only to NASA Headquarters.

2. Proposals cannot be received by NASA on Saturdays or Sundays or Federal holidays.

6.4 Deadline for Proposal Receipt

Deadline for receipt of Phase I proposals at NASA is 4:00 p.m., EDT, July 16, 1990. NASA assumes no responsibility for evaluating proposals received after the stated deadline. Offerors are cautioned to be careful of unforseen delays that can cause late arrival of proposals at NASA with the result that they may not be evaluated. Nevertheless, should such actions be deemed to be in the best interests of the government, NASA reserves the right to accept late proposals or modifications to otherwise acceptable proposals received before the stated deadline. Such acceptances would be made only under unusual and justifiable circumstances and when they would not provide unfair competitive advantages to the offerors.

6.5 Acknowledgement of Proposal Receipt

NASA will acknowledge receipt of proposals by a postal card mailed to the company official endorsing the proposal cover sheet. If a proposal acknowledgement card is not received from NASA within 30 days following the closing date of this Solicitation, the offeror should call 202-453-8702. **NASA will not accept telephone inquiries regarding receipt of proposals prior to August 15, 1990.**

6.6 Withdrawal of Proposals

Proposals may be withdrawn by written notice or telegram (including mailgram) received at any time before award. Proposals may be withdrawn in person by an offeror or an authorized representative, if the representative's identity is made known and the representative signs a receipt for the proposal.

7.0 SCIENTIFIC AND TECHNICAL INFORMATION SOURCES

The following organizations can provide technology search and/or document services and can be contacted directly for service and cost information.

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4600

Aerospace Research Applications Center
Indianapolis Center for Advanced Research
611 N. Capitol Avenue
Indianapolis, IN 46204
(317) 262-5003

Central Industrial Applications Center
Rural Enterprises, Inc.
P.O. Box 1335
Durant, OK 74702
(405) 924-6822

Southern Technology Applications Center
One Progress Boulevard
Box 24
Progress Center
Alachua, FL 32615
(904) 462-3913

NASA Industrial Applications Center
823 William Pitt Union
University of Pittsburgh
Pittsburgh, PA 15260
(412) 648-7010

NASA/UK Technology Applications Center
University of Kentucky
109 Kinkead Hall
Lexington, KY 40506-0057
(606) 257-6322

NERAC, Inc.
One Technology Drive
Tolland, CT 06084
(203) 872-7000

NASA Industrial Applications Center
University of Southern California
Research Annex
3716 S. Hope Street Rm 200
Los Angeles, CA 90007-4344
(213) 743-8988
Attention: Radford King

Technology Applications Center
2808 Central, S.E.
University of New Mexico
Albuquerque, NM 87131
(505) 277-3622

Computer Software Management and Information Center
382 East Broad Street
University of Georgia
Athens, GA 30602
(404) 542-3265

North Carolina Science and Technology Research Center
P.O. Box 12235
Research Triangle Park, NC 27709
(919) 549-0671

NASA/SU Industrial Applications Center
Southern University
P.O. Box 9737
Baton Rouge, LA 70813-9737
(504) 771-6272

8.0 TECHNICAL TOPICS

Proposals shall address subtopics in Appendix E under the following technical topics:

01.00 Aeronautical Propulsion and Power
02.00 Aerodynamics and Acoustics
03.00 Aircraft Systems, Subsystems, and Operations
04.00 Materials and Structures
05.00 Teleoperators and Robotics
06.00 Computer Sciences and Applications
07.00 Information Systems and Data Handling
08.00 Instrumentation and Sensors
09.00 Spacecraft Systems and Subsystems
10.00 Space Power
11.00 Space Propulsion
12.00 Human Habitability and Biology in Space
13.00 Quality Assurance, Safety, and Check-Out for Ground and Space Operations
14.00 Satellite and Space Systems Communications
15.00 Materials Processing, Micro-Gravity, and Commercial Applications in Space

APPENDIX A - PROPOSAL COVER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION PROPOSAL COVER
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
90-1	___ . ___	______	____

ENTER PROPOSAL NUMBER ON APPENDICES B & C

PROJECT TITLE ______________________________

____

FIRM NAME ______________________________

MAIL ADDRESS ______________________________

CITY ______________ STATE ______ ZIP CODE ______________

AMOUNT REQUESTED $ __________ (PHASE I) DURATION ______ MONTHS (PHASE I)

OFFEROR CERTIFIES THAT:

	YES	NO
1. As defined in Section 2 of the Solicitation, this firm qualifies as a:		
1.1 Small business	☐	☐
1.2 Minority and disadvantaged small business	☐	☐
1.3 Women-owned small business	☐	☐
NOTE: 1.2 and 1.3 are not eligibility requirements for SBIR and the offeror may decline to indicate status by stating "Decline" across boxes.		
2. A minimum of two-thirds of the research and/or analytical effort for this project will be carried out within the firm if an award is made.	☐	☐
3. The primary employment of the principal investigator will be with this firm at the time of award and during the conduct of the research.	☐	☐
4 Proposals of similar content have (indicate Yes) or have not (indicate No) been submitted to another agency and the details required by Section 5.10 of the Solication are included in the proposal.	☐	☐

ENDORSEMENTS

	Principal Investigator	Corporate/Business Official
Typed Name	______________	______________
Title	______________	______________
Telephone No.	______________	______________

Signature of Principal Investigator ______________ Date ______________

Signature of Corporate Business Official ______________ Date ______________

PROPRIETARY NOTICE (IF APPLICABLE, SEE SECTION 5.4a, 5.5)

NOTICE: No proprietary information is included except in a Proprietary Addendum. The information (data) on pages __________ in the Proprietary Addendum section of this proposal constitute a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, in the event a contract is awarded on this proposal, the Government may obtain additional rights to use and disclose this information (data).

INSTRUCTIONS FOR COMPLETING APPENDIX A AND APPENDIX B

General:

To facilitate proposal processing, NASA intends to employ automated optical devices to record proposal information wherever possible. Towards this end, it is desirable, but not required, that the proposal cover sheet (Appendix A) and the project summary (Appendix B) be typed without proportional spacing using one of the following typestyles:

Courier 12 10 or 12 pitch
Courier 72 10 pitch
Elite 72
Letter Gothic 10 or 12 pitch
OCR-B 10 or 12 pitch
Pica 72 10 pitch
Prestige Elite 10 or 12 pitch
Prestige Pica 10 pitch

Please complete and ***submit the original red forms*** bound in this solicitation (not photocopies). The completed forms can then be copied for use as pages 1 and 2 of your proposal. The original red forms should be submitted in addition to the five copies of your total proposal (see section 6.2 "Physical Packaging Requirements").

Carefully align the forms in the typewriter using the underlines as a guide. The forms are printed to accommodate standard typewriting spacing.

Appendix A:

1. ***Proposal Number:*** Complete the proposal number as follows:
   a. Enter 4 digit subtopic number.
   b. Enter the last four digits of your firm's telephone number.
   c. If you are submitting different proposals under the same subtopic, enter a change letter as appropriate to differentiate proposal numbers.

Example: 1. Firm, telephone 273-8126, submits one proposal to subtopic 06.03. Proposal number is: ***06.03 8126.***

Example: 2. Firm, telephone 392-4826, submits three different proposals to subtopic 11.03. Proposal numbers are:

11.03 4826
11.03 4826A
11.03 4826B

2. ***Project Title:*** Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title.
3. ***Firm Name:*** Enter full name of company submitting the proposal. If a joint venture, list company chosen to negotiate and receive contracts. If name exceeds 30 keystrokes, please abbreviate.
4. ***Address:*** Enter mail address.
   State: Enter 2 letter designation (example Maine—ME)
   Zip-Code: Enter 5 or 9 digit code
5. ***Amount Requested:*** Enter proposal amount from budget summary. Round to nearest dollar. ***Do not*** enter cents.
6. ***Duration:*** Enter proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss reason in the text of the proposal.
7. ***Certifications:*** Enter Y for yes or N for no in the appropriate boxes in response to statements or questions.
8. ***Endorsements:*** The proposal should be signed by the proposed principal investigator ***and*** an official of the firm qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person.

Appendix B:

1. ***Proposal Number:*** Enter the same proposal number as shown on your Proposal Cover Sheet.
2. ***Project Title:*** Enter the same title as shown on your Proposal Cover Sheet.
3. ***Technical Abstract:*** Provide a summary of 200 words or less of your proposed project. The abstract must not contain proprietary information.
4. ***Potential Commercial Applications of the Research:*** Summarize the commercial potential of the project assuming the results of the proposed research or R&D are achieved.
5. ***Key Words:*** Provide no more than 8 key words descriptive of the project and useful in identifying the technology, research thrust or application of the proposed effort
6. ***Name and Address of Firm:*** Enter firm name and mail address as shown on the Proposal Cover Sheet.
7. ***Principal Investigator:*** Enter name of the Principal Investigator as shown on the Proposal Cover Sheet.

APPENDIX A - PROPOSAL COVER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION PROPOSAL COVER
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
90-1	___ . ___	______	_____

ENTER PROPOSAL NUMBER ON APPENDICES B & C

PROJECT TITLE ______________________________

____

FIRM NAME ______________________________

MAIL ADDRESS ______________________________

CITY ______________ STATE ______ ZIP CODE ______________

AMOUNT REQUESTED $ __________ (PHASE I) DURATION ______ MONTHS (PHASE I)

OFFEROR CERTIFIES THAT:

	YES	NO
1. As defined in Section 2 of the Solicitation, this firm qualifies as a:		
1.1 Small business	☐	☐
1.2 Minority and disadvantaged small business	☐	☐
1.3 Women-owned small business	☐	☐
NOTE: 1.2 and 1.3 are not eligibility requirements for SBIR and the offeror may decline to indicate status by stating "Decline" across boxes.		
2. A minimum of two-thirds of the research and/or analytical effort for this project will be carried out within the firm if an award is made.	☐	☐
3. The primary employment of the principal investigator will be with this firm at the time of award and during the conduct of the research.	☐	☐
4 Proposals of similar content have (indicate Yes) or have not (indicate No) been submitted to another agency and the details required by Section 5.10 of the Solication are included in the proposal.	☐	☐

ENDORSEMENTS

	Principal Investigator	Corporate/Business Official
Typed Name	______________	______________
Title	______________	______________
Telephone No.	______________	______________

Signature of Principal Investigator ______________ Date ______________

Signature of Corporate Business Official ______________ Date ______________

PROPRIETARY NOTICE (IF APPLICABLE, SEE SECTION 5.4a, 5.5)

NOTICE: No proprietary information is included except in a Proprietary Addendum. The information (data) on pages __________ in the Proprietary Addendum section of this proposal constitute a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, in the event a contract is awarded on this proposal, the Government may obtain additional rights to use and disclose this information (data).

INSTRUCTIONS FOR COMPLETING APPENDIX A AND APPENDIX B

General:

To facilitate proposal processing, NASA intends to employ automated optical devices to record proposal information wherever possible. Towards this end, it is desirable, but not required, that the proposal cover sheet (Appendix A) and the project summary (Appendix B) be typed without proportional spacing using one of the following typestyles:

Courier 12 10 or 12 pitch
Courier 72 10 pitch
Elite 72
Letter Gothic 10 or 12 pitch
OCR-B 10 or 12 pitch
Pica 72 10 pitch
Prestige Elite 10 or 12 pitch
Prestige Pica 10 pitch

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Carefully align the forms in the typewriter using the underlines as a guide. The forms are printed to accommodate standard typewriting spacing.

Appendix A:

1. ***Proposal Number:*** Complete the proposal number as follows:
   a. Enter 4 digit subtopic number.
   b. Enter the last four digits of your firm's telephone number.
   c. If you are submitting different proposals under the same subtopic, enter a change letter as appropriate to differentiate proposal numbers.

Example: 1. Firm, telephone 273-8126, submits one proposal to subtopic 06.03. Proposal number is: ***06.03 8126.***

Example: 2. Firm, telephone 392-4826, submits three different proposals to subtopic 11.03. Proposal numbers are:

11.03 4826
11.03 4826A
11.03 4826B

2. ***Project Title:*** Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title.
3. ***Firm Name:*** Enter full name of company submitting the proposal. If a joint venture, list company chosen to negotiate and receive contracts. If name exceeds 30 keystrokes, please abbreviate.
4. ***Address:*** Enter mail address.
   State: Enter 2 letter designation (example Maine—ME)
   Zip-Code: Enter 5 or 9 digit code
5. ***Amount Requested:*** Enter proposal amount from budget summary. Round to nearest dollar. ***Do not*** enter cents.
6. ***Duration:*** Enter proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss reason in the text of the proposal.
7. ***Certifications:*** Enter Y for yes or N for no in the appropriate boxes in response to statements or questions.
8. ***Endorsements:*** The proposal should be signed by the proposed principal investigator ***and*** an official of the firm qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person.

Appendix B:

1. ***Proposal Number:*** Enter the same proposal number as shown on your Proposal Cover Sheet.
2. ***Project Title:*** Enter the same title as shown on your Proposal Cover Sheet.
3. ***Technical Abstract:*** Provide a summary of 200 words or less of your proposed project. The abstract must not contain proprietary information.
4. ***Potential Commercial Applications of the Research:*** Summarize the commercial potential of the project assuming the results of the proposed research or R&D are achieved.
5. ***Key Words:*** Provide no more than 8 key words descriptive of the project and useful in identifying the technology, research thrust or application of the proposed effort
6. ***Name and Address of Firm:*** Enter firm name and mail address as shown on the Proposal Cover Sheet.
7. ***Principal Investigator:*** Enter name of the Principal Investigator as shown on the Proposal Cover Sheet.

APPENDIX A - PROPOSAL COVER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION PROPOSAL COVER
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
90-1	____	____	____

ENTER PROPOSAL NUMBER ON APPENDICES B & C

PROJECT TITLE ____________________

____

FIRM NAME ____________________

MAIL ADDRESS ____________________

CITY ____________ STATE ______ ZIP CODE ____________

AMOUNT REQUESTED $ __________ (PHASE I) DURATION ______ MONTHS (PHASE I)

OFFEROR CERTIFIES THAT:

	YES	NO
1. As defined in Section 2 of the Solicitation, this firm qualifies as a:		
1.1 Small business	☐	☐
1.2 Minority and disadvantaged small business	☐	☐
1.3 Women-owned small business	☐	☐
NOTE: 1.2 and 1.3 are not eligibility requirements for SBIR and the offeror may decline to indicate status by stating "Decline" across boxes.		
2. A minimum of two-thirds of the research and/or analytical effort for this project will be carried out within the firm if an award is made.	☐	☐
3. The primary employment of the principal investigator will be with this firm at the time of award and during the conduct of the research.	☐	☐
4 Proposals of similar content have (indicate Yes) or have not (indicate No) been submitted to another agency and the details required by Section 5.10 of the Solication are included in the proposal.	☐	☐

ENDORSEMENTS

	Principal Investigator	Corporate/Business Official
Typed Name		
Title		
Telephone No.		

Signature of Principal Investigator ____________ Date ____________

Signature of Corporate Business Official ____________ Date ____________

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General:

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Elite 72
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1. ***Proposal Number:*** Enter the same proposal number as shown on your Proposal Cover Sheet.
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APPENDIX B - PROJECT SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
90-1	____	____	____

AMOUNT REQUESTED: $

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS OF THE RESEARCH

KEY WORDS
(LIMIT 8)

NAME AND ADDRESS OF OFFEROR

PRINCIPAL INVESTIGATOR

INSTRUCTIONS FOR COMPLETING APPENDIX A AND APPENDIX B

General:

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APPENDIX B - PROJECT SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION
(Instructions on Reverse Side)

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(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
90-1	___ . ___	_____	___

AMOUNT REQUESTED: $

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APPENDIX B - PROJECT SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION
(Instructions on Reverse Side)

PROPOSAL NUMBER
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90-1	__ . __	____	___

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Appendix B:

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APPENDIX C - SBIR PROPOSAL SUMMARY BUDGET

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION
(Instructions on Reverse Side)

FIRM:

PROPOSAL NUMBER:

PRINCIPAL INVESTIGATOR:

(See Instructions on Back of Form)	TOTAL PRICE
MATERIAL:	$
PERSONNEL:	$
OTHER DIRECT COSTS:	$
OVERHEAD:	$
GENERAL AND ADMINISTRATIVE (G&A):	$
PROFIT:	$
TOTAL PRICE PROPOSED	$

TYPED NAME AND TITLE:

SIGNATURE:

THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 90-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE.

DATE SUBMITTED

INSTRUCTIONS

The purpose of this form is to provide a vehicle whereby the offeror submits to the Government a pricing proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting system.

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, on a budget explanation page immediately following the budget in the proposal. (See below for discussion on various categories).

1. **MATERIALS —**
   a. *Materials and Supplies.* Indicate types required and estimate costs.
   b. *Publication Costs/Page Charges.* Estimate cost of preparing and publishing project results.
   c. *Consultant Services.* Indicate name, daily compensation, and estimated days of service.
   d. *Computer Services.* Include justification. Computer equipment leasing is included here. Purchase of equipment is included under OTHER DIRECT COSTS.
   e. *Subcontracts.* Include a completed budget and justify details.
   f. *Other.* Itemize and justify.
2. **PERSONNEL** — On the budget explanation page, list individually all personnel included, the requested person-months to be funded, and rates of pay (salary, wages, and fringe benefits).
3. **OTHER DIRECT COSTS** — List all other direct costs which are not otherwise included in the categories described above. For travel, address the type and extent of travel and its relation to the project. List each item of permanent equipment to be purchased, its price, and explain its relation to the project.
4. **OVERHEAD** — Specify current rate(s) and base(s). Use current rate(s) negotiated with the cognizant Federal negotiating agency, if available. If no rate(s) has (have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I which will be subject to approval by NASA. If a current negotiated rate(s) is (are) not available for Phase II, NASA will negotiate an approved rate(s) with the offeror. The offeror may use whatever number and types of overhead rates that are in accordance with the firm's accounting system and approved by the cognizant Federal negotiating agency, if available.
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APPENDIX C - SBIR PROPOSAL SUMMARY BUDGET

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION
(Instructions on Reverse Side)

FIRM:

PROPOSAL NUMBER:

PRINCIPAL INVESTIGATOR:

	TOTAL PRICE
(See Instructions on Back of Form) MATERIAL:	$
PERSONNEL:	$
OTHER DIRECT COSTS:	$
OVERHEAD:	$
GENERAL AND ADMINISTRATIVE (G&A):	$
PROFIT:	$
TOTAL PRICE PROPOSED	$

TYPED NAME AND TITLE:

SIGNATURE:

THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 90-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE.

DATE SUBMITTED

PROPOSAL PAGE NO.

INSTRUCTIONS

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APPENDIX C - SBIR PROPOSAL SUMMARY BUDGET

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 90-1 SOLICITATION
(Instructions on Reverse Side)

FIRM: PROPOSAL NUMBER:

PRINCIPAL INVESTIGATOR:

(See Instructions on Back of Form)

	TOTAL PRICE
MATERIAL:	$
PERSONNEL:	$
OTHER DIRECT COSTS:	$
OVERHEAD:	$
GENERAL AND ADMINISTRATIVE (G&A):	$
PROFIT:	$
TOTAL PRICE PROPOSED	$

TYPED NAME AND TITLE: SIGNATURE:

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   - f. *Other.* Itemize and justify.
2. **PERSONNEL** — On the budget explanation page, list individually all personnel included, the requested person-months to be funded, and rates of pay (salary, wages, and fringe benefits).
3. **OTHER DIRECT COSTS** — List all other direct costs which are not otherwise included in the categories described above. For travel, address the type and extent of travel and its relation to the project. List each item of permanent equipment to be purchased, its price, and explain its relation to the project.
4. **OVERHEAD** — Specify current rate(s) and base(s). Use current rate(s) negotiated with the cognizant Federal negotiating agency, if available. If no rate(s) has (have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I which will be subject to approval by NASA. If a current negotiated rate(s) is (are) not available for Phase II, NASA will negotiate an approved rate(s) with the offeror. The offeror may use whatever number and types of overhead rates that are in accordance with the firm's accounting system and approved by the cognizant Federal negotiating agency, if available.
5. **GENERAL AND ADMINISTRATIVE (G&A)** — Specify current rate and base. Use current rate negotiated with the cognizant Federal negotiating agency, if available. If no rate has been negotiated, a reasonable indirect cost (overhead) rate may be requested for Phase I which will be subject to approval by NASA. If a current negotiated rate is not available for Phase II, NASA will negotiate an approved rate with the offeror.

APPENDIX D

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SBIR 90-1 SOLICITATION

PROPOSAL CHECK LIST

Company/Name
and Address: ______________________________

____

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Proposal Number: ______________________________

Proposal Title: ______________________________

____

CHECK

__ 1. Offeror has read Solicitation pages 1-17 and understands that proposals not meeting all requirements may be nonresponsive and may not be evaluated.

__ 2. Proposal and innovation is submitted in only one Subtopic (see Sect. 5.14-d).

__ 3. All information required by Sect. 3.3 is included in order.

__ 4. Any proprietary information, if included, is contained in a Proprietary Addendum with required Proprietary Notice (see Sect. 5.4-a).

__ 5. Certifications and Signatures on Appendices A and C.

__ 6. Period of technical performance does not exceed 6 months and funding request does not exceed $50,000.

__ 7. Proposal (including any supplementary material and/or Proprietary Addendum) contains no more than 25 - 8½ x 11 inch pages. Check list is not included in page count.

__ 8. Proposed innovation is described in first paragraph of proposal Part D-Sect. 1.

__ 9. Phase II objectives are discussed.

__ 10. Phase III potential (NASA and commercial applications) and possible approach discussed.

__ 11. Proposal package includes:

    a. Five (5) copies of Proposal
    b. Original Cover Sheet and Proposal Summary (red forms, Appendices A and B) clipped (not stapled) to Check List.

__ 12. Offeror understands that proposals must be received in NASA Headquarters by 4 p.m. EDT July 16, 1990.

Signature of person completing this Check List: ______________________________

APPENDIX E Subtopics

Field Centers[1]

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	
01.00										**AERONAUTICAL PROPULSION AND POWER**
01.01							■			Internal Fluid Mechanics for Aeronautical Propulsion Systems
01.02							■			Aeronautical Propulsion System Components
01.03							■			Aeronautical Propulsion System Instrumentation, Sensors and Controls
01.04							■			Novel Aeronautical Propulsion Concepts
02.00										**AERODYNAMICS AND ACOUSTICS**
02.01	■									Computational Fluid Dynamics
02.02						■				Theoretical Aerodynamics and Viscous Flow
02.03						■				Hypersonic Vehicle Aerothermodynamics
02.04								■		Rarefied Gas Dynamics
02.05								■		Plume-Induced Effects on Launch and Orbital Vehicles
02.06	■									Configurational Aerodynamics Including Vortices
02.07	■									Rotorcraft Aerodynamics and Dynamics
02.08						■				Wind Tunnel Design and Experimental Techniques
02.09						■				Wind Tunnel Instrumentation
02.10						■				Aircraft Noise Prediction and Reduction
02.11							■			Propulsion Noise Reduction
03.00										**AIRCRAFT SYSTEMS, SUBSYSTEMS, AND OPERATIONS**
03.01							■			Aircraft Ice Protection Systems
03.02						■				Aircraft Severe Weather Environment
03.03						■				Control Concepts for Fixed Wing Aircraft
03.04	■									Fully Automatic Guidance for Rotorcraft
03.05	■									Flight Research Sensors and Instrumentation
03.06	■									Aircraft Flight Testing Techniques
03.07						■				Hypersonic Flight Systems Technology
03.08	■									Very High Altitude Aircraft Technology
03.09	■									Aeronautical Human Factors and Flight Management Systems
03.10	■									Development, Testing and Verification of Flight Critical Systems
03.11	■									Integrated Aerospace Vehicle Flight Characteristics Simulation

[1] *Legend appears on page 25*

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Field Centers

04.00 MATERIALS AND STRUCTURES

No.	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	Title
04.01							■			High Temperature Composite Materials Technology for Aeropropulsion Applications
04.02							■			Processing of High Temperature Composite Materials for Aeropropulsion Systems
04.03							■			Improved Fibers for High Temperature Composites for Power and Propulsion
04.04								■		Environment-Resistant Alloys for Launch Vehicle and Space Propulsion Systems
04.05							■			Computational Structural Methods for Aeropropulsion Applications
04.06						■				Composite Materials for Aerostructures and Space Applications
04.07						■				Light Alloy Metallics for Airframe Structures
04.08								■		Welding Technology
04.09						■				Nondestructive Evaluation Technology to Characterize Material Properties
04.10					■					Bond Strength of Thermal Sprayed Coatings
04.11		■								Special Purpose Materials, Processes and Testing for Space Flight Applications
04.12	■									Thermal Protection Materials and Systems
04.13			■							Adaptive Deployable Structures
04.14				■						Spacecraft Structures and Mechanisms
04.15			■				■			High Temperature Superconductors for Aerospace Applications
04.16				■						Lunar Materials Utilization

05.00 TELEOPERATORS AND ROBOTICS

No.	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	Title
05.01						■				Large Scale Telerobotoc Systems
05.02		■								Telerobotic and Biomechanical System Software Development
05.03		■								Telerobotic Electro/Mechanical Systems
05.04				■						Space Based Manipulator Mechanisms and Controls
05.05				■						Artificial Intelligence for Space Station Applications
05.06			■							Supervised Autonomous Servicing Technology
05.07							■			Space Mechanisms
05.08				■						Robotic Adaptive Grasping and Manipulation Systems
05.09								■		Mission Support Flight Robotics

Field Centers

06.00	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	**COMPUTER SCIENCE AND APPLICATIONS**
06.01						■				Engineering Computer Science
06.02		■								Software Development and Maintenance
06.03						■				Reliable Software Development
06.04	■									Knowledge-Based Systems Technologies for Aerospace Applications
06.05				■						Software Systems for Mission Planning and Flight Control
06.06	■									Computer Sciences in Computational Physics
06.07			■							Large Multiprocessor Database Technology
06.08		■								Space Flight Data Systems
06.09					■					Shuttle and Payload Ground Processing Systems
06.10	■									Optical Processing Technology
06.11						■				Analysis and Synthesis of Engineering Systems

07.00	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	**INFORMATION SYSTEMS AND DATA HANDLING**
07.01						■				Focal-Plane Image Processing
07.02		■								Earth Observing System Data Technologies
07.03									■	Simulation Model for Multispectral Sensors and Imaging Systems
07.04									■	Spatial Data Management and Geographic Information Systems
07.05									■	Geographic Information System Software Development
07.06						■				Information Processing Technology and Integrated Data Systems
07.07								■		Advanced Remote Sensing Database Technology
07.08		■								Heterogenous Distributed Data Management
07.09			■							Spacecraft On-Board Infromation Extraction
07.10		■								Computational Libraries for Massively Parallel Computing Systems
07.11			■							Planetary Data System Educational Software

08.00	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	**INSTRUMENTATION AND SENSORS**
08.01		■								Earth Atmospheric Sensing and Topographic Measurements from Space
08.02									■	Low-Cost, High Resolution, Airborne, Remote Sensing Instrumentation for Earth Sciences
08.03						■				Sensors for Aerosol and Cloud Studies
08.04		■								Laser Polarization Profiling

Field Centers

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	INSTRUMENTATION AND SENSORS (continued)
08.05		X								Earth Atmospheric LIDAR Remote Sensing
08.06						X				Tunable Solid-State Lasers, Detectors, and LIDAR Subsystems
08.07								X		Earth Observing Sensor Development for Geostationary Orbit
08.08			X							A Cold Coronagraph for Planetary Observations
08.09		X	X							Detetectors and Detector Arrays
08.10		X								Laser Heterodyne Technology
08.11	X		X							Infrared Technology for Astronomical Applications
08.12								X		Infrared Spectroscopy with Detector Arrays
08.13			X							High-Operating-Temperature Infrared Detector Arrays
08.14			X							Submillimeter Antennas, Radiometers and Spectrometers
08.15			X							High-Field Vector Helium Magnetometer for Space Applications
08.16	X									Instrument Technology for Exobiology
08.17			X							Instrumentation for Geology
08.18		X	X							Oceanographic Instrumentation
08.19		X	X							Optical Components and Design Tools
08.20								X		Optical Fabrication and Metrology
08.21		X								Spacecraft Contamination Monitoring
08.22		X								High Resolution Charged Particle Instrumentation
08.23		X								Detectors for Gamma Ray Astronomy
08.24			X							Gamma Ray and X-Ray Spectoscopy
08.25								X		Underwater Position Three Dimensional Measuring System
08.26					X					Non-invasive Fluid Measuring Instrument

09.00 SPACECRAFT SYSTEMS AND SUBSYSTEMS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	
09.01						X				Control of Large Space Structures
09.02						X				Guidance, Navigation and Control of Advanced Space Transportation Systems
09.03		X								Digital Processor for an Earth Horizon Scanner Attitude Control System
09.04		X								Spacecraft Flight Dynamics
09.05				X						Tracking System for STS, Space Station, Lunar and Mars Missions, and Robotics
09.06				X						Space Station Crew Workstation Displays and Controls
09.07			X							Spacecraft Data Transfer Using Monolithic Microwave Integrated Circuits

Field Centers

No.	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	SPACECRAFT SYSTEMS AND SUBSYSTEMS (continued)
09.08		■								Sensor Applications of Monolithic Microwave Integrated Circuits
09.09			■							Cyrogenic Refrigeration Systems
09.10		■								Thermal Control for Unmanned Spacecraft
09.11				■						Thermal Management Systems for Manned Lunar and Planetary Missions
09.12								■		Manned Spacecraft Thermal Systems
09.13								■		Fluid Management, Leak Detection, and Fire Suppressants for Manned Missions
09.14	■									Spacecraft Plasma Environment Forecasting
09.15		■								Technologies for Long Duration Scientific Balloons
10.00										**SPACE POWER**
10.01							■			Space Energy Conversion Systems
10.02		■								Optical Coating for Aerospace Solar Cell Cover-Glasses
10.03			■							Thermal-to-Electric Conversion Technology
10.04						■				Photovoltaic-Laser Energy Converters
10.05							■			Space Electrochemical Storage Systems
10.06			■							High Specific Energy and Long Life Batteries
10.07				■						Portable Rechargeable Energy Storage for Space Station Applications
10.08							■	■		Space Power Management and Distribution
10.09				■						Electrical Power Control and Distribution Subsystems
10.10			■							Flexible Magnetic Circuit Components for Space Power
11.00										**SPACE PROPULSION**
11.01								■		Propulsion System Combustion Processes
11.02								■		Liquid Engine Internal Flow Dynamics
11.03								■		Solid Rocket Motor Technology
11.04							■			Space Propulsion Systems for Orbit-to-Orbit and Injection/Transfer Vehicles
11.05							■			Unconventional Rocket Engines for Altitude Compensation and Throttling
11.06							■			Low Reynolds Number and Plume Flows
11.07							■			Diagnostics for Chemical Rocket Engines
11.08							■			Fiber Optic Measurement Technology for Cyrogenic Liquid Propulsion Systems
11.09									■	Propulsion Ground Testing Technology

Field Centers

12.00 HUMAN HABITABILITY AND BIOLOGY IN SPACE

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	
12.01				■						Medical Sciences for Manned Space Programs
12.02				■				■		Biomedical and Environmental Health Support for Manned Space Programs
12.03	■			■				■		Regenerative Life Support; Air, Water, and Waste Management
12.04	■				■					Bioregenerative Food Production
12.05	■			■				■		Human Factors for Space Crews
12.06				■						Intra-Vehicular Systems for Space Crews
12.07	■			■						Extra-Vehicular Activity
12.08	■									Human Factors for Long Duration Space Missons
12.09								■		Man-Space Systems Integration
12.10	■									Life Sciences Spaceflight Technology
12.11					■					Miniature Biomedical Telemetry Instrument
12.12								■		One-Atmosphere-Pressure Underwater Suit

13.00 QUALITY ASSURANCE, SAFETY, AND CHECK-OUT FOR GROUND AND SPACE ORGANIZATIONS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	
13.01					■					Halon Replacement for Use in Electronic Facility Fire Protection Systems
13.02					■					Portable Inductive Welder with Integral Weld Verification
13.03					■					Launch and Ground Weather Forecasting
13.04					■					Fluids and Fluid Systems Components
13.05								■		Flowmeter Test and Calibration
13.06				■						Test Facility Instrumentation and Safety Devices
13.07			■							Quality Assurance of Very Large Scale Integrated (VLSI) Circuits
13.08					■					Nondestructive Evaluation Inspection Techniques for Launch Readiness Verification

14.00 SATELLITE AND SPACE SYSTEMS COMMUNICATIONS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	
14.01				■						Communications for Manned Space Systems
14.02		■								Advanced Data Relay Satellite Systems
14.03			■							Millimeter Wave Deep Space Communications Components
14.04			■							Spacecraft Telecommunications Systems
14.05							■			Advanced Satellite Communications Systems
14.06			■							Optical Communication for Deep Space
14.07							■			Low Cost Ka-Band Ground Terminals
14.08			■							Laser Position Modulators for Optical Communications

Field Centers

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	**15.00 MATERIALS PROCESSING, MICRO-GRAVITY, AND COMMERCIAL APPLICATIONS IN SPACE**
15.01										Materials Processing in Space
15.02										Microgravity Science, Technology and Engineering Experiments
15.03										Chemical Vapor Deposition Analysis and Modeling Tools

LEGEND

ARC — Ames Research Center
Moffett Field, CA

GSFC — Goddard Space Flight Center
Greenbelt, MD

JPL — Jet Propulsion Laboratory
Pasadena, CA

JSC — Johnson Space Center
Houston, TX

KSC — Kennedy Space Center
Kennedy Space Center, FL

LaRC — Langley Research Center
Hampton, VA

LeRC — Lewis Research Center
Cleveland, OH

MSFC — Marshall Space Flight Center
Huntsville, AL

SSC — Stennis Space Center
Stennis Space Center, MS

01.00 AERONAUTICAL PROPULSION AND POWER

01.01 INTERNAL FLUID MECHANICS FOR AERONAUTICAL PROPULSION SYSTEMS
Center: LeRC

Innovative techniques are sought for analyzing flows in aeronautical propulsion systems for low subsonic through hypersonic speeds. Areas of interest include:

- Computational methods unique to internal flows: Application of parallel processing, expert systems, innovative graphics, user oriented geometry description and mesh generation techniques, new algorithms employing solution-adaptive mesh clustering strategies.

- Inlets and nozzles: Advanced steady-state and time-dependent flow analyses and benchmark data for component and systems performance, boundary layers, bleed flows, diffusion, jet mixing, separated flow, heat transfer, surface cooling, and external spillage.

- Turbomachinery: Advanced flow codes, physical models, and supporting validation data for both steady and unsteady flows including shocks, viscous effects, heat transfer, and tip-clearance effects in fans, compressors and turbines. Novel concepts for instrumentation and flow visualization.

- Combustors and augmenters: Highly efficient flow codes and innovative means to supply validation data for the flows, physical processes, and reaction mechanisms in a combustor including fuel injection, spray evaporation and mixing, and basic reaction mechanisms and kinetic rates for hydrocarbon oxidation and soot formation.

01.02 AERONAUTICAL PROPULSION SYSTEM COMPONENTS
Center: LeRC

Proposals are solicited in three areas: turbine engines, rotary combustion engines and drive train technology.

- Turbine engines: Innovative improvements are needed for inlets, propeller/fans, compressors, combustors, turbines, nozzles, and recuperators/regenerators. Objectives include:

  - Greater cycle efficiency;
  - Lower gaseous and particulate emissions;
  - Reduced coolant penalties using advanced materials;
  - Reduced weight, volume, and aerodynamic drag.

- Rotary combustion engines: Novel, innovative engine components, materials and subsystems are desired for advanced Wankel-type rotary engines capable of burning jet fuel effectively. Areas of interest and objectives include:

  - High-speed, high output, multi-fuel combustion system elements, including fuel delivery and ignition methods;
  - Seals, bearings and lubricants;
  - Materials and fabrication technology for lightweight and/or heat resistant (insulating) structural components, such as rotors and trochoid and end housings;
  - Turbocharger/turbocompounding in the 0.5 to 1.5 lb/sec flow range having single-stage pressure ratios of up to 8:1.

- Drive train technology: New concepts are solicited which would decrease drive system weight and noise and increase reliability and strength. Areas of interest include:

  - Lubricants and gear and bearing materials for gear box operating temperatures >200 °C;
  - Transmission health monitoring systems;
  - Gear tooth forms for lower noise and better lubricant action;
  - Transmission concepts for large, high HP gear boxes;
  - Transmission noise prediction methods;
  - Elastohydrodynamic film thickness predictive methods for bevel gear sets;
  - Expert systems and optimization methods for gear and transmission design.

01.03 AERONAUTICAL PROPULSION SYSTEM INSTRUMENTATION, SENSORS AND CONTROLS
Center: LeRC

The increased thermal and aerodynamic loads to which advanced propulsion system components will be exposed demand that precise measurements of the severe operating

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environment and engine conditions be made for control, safety, and health monitoring considerations. Innovative techniques and instrumentation are sought for accurate, minimally intrusive measurement of pressure, temperature, strain, flow, and other parameters important to achieving that objective and for verification of design codes, development of advanced aerospace propulsion systems, and operation and control of these systems.

- Strain and temperature measurements on both metal and ceramic surfaces up to 1900 °C.
- Gas temperature and pressure measurements, both static and dynamic for up to 1900 °C.
- High-temperature electronics and integrated sensors.
- Fiber-optic-based sensors and control systems.
- Aerodynamic flow and combustion diagnostic systems.
- Data processing techniques for non-intrusive whole-field measurement systems.

New, powerful onboard computing capability and new sensor technology will enable achievement of optimum engine performance and life by incorporating artificial intelligence and feedback control. To achieve these objectives innovations are sought in:

- Real-time identification.
- Nonlinear or adaptive real-time control design.
- Reliability enhancement through redundancy management or fault detection.
- Improved component performance through compressor stall alleviation, combustor pattern factor control, or other advanced techniques.
- Integrated system intelligence.
- High speed computation for artificial intelligence applications.

01.04 NOVEL AERONAUTICAL PROPULSION CONCEPTS
Center: LeRC

Major improvements in propulsion system performance, weight, bulk, and cost are required for many important future aeronautical vehicles, especially for high-speed accelerators for transatmospheric vehicles and efficient cruise powerplants for supersonic and hypersonic airplanes. This subtopic solicits proposals to identify and analyze feasible, realistic, improved, or new airbreathing propulsion system concepts that would enable major advances to be made in vehicle capabilities. Current advanced propulsion concepts include variable-cycle engines, air-turboramjets, dual-mode (subsonic/supersonic combustion) scramjets, and air-augmented rockets. Proposed advanced propulsion systems could utilize conventional fuels, high-density hydrocarbons, slurries, cryogenic methane, or hydrogen.

To qualify for evaluation, Phase I proposals must: (1) have clear applications to the aero objectives stated above, (2) include technically sound first-order system concept modeling and/or valid comparative evaluations against conventional powerplant baselines or other advanced alternatives to support postulated desirability and feasibility, and (3) suggest realistic, hardware-oriented Phase II R&D continuations directed toward experimental verification of key elements of proposed concepts which are suitable for pursuit by NASA and by the small business in the near future within the scope of the SBIR program.

02.00 AERODYNAMICS AND ACOUSTICS

02.01 COMPUTATIONAL FLUID DYNAMICS
Center: ARC

More powerful numerical computation capabilities for predicting fundamental fluid flow phenomena can lead to improved aerodynamic characteristics and optimal configurations for advanced aircraft, missiles and aerospace vehicles of every type and application. NASA's interest in computational fluid

dynamics (CFD) encompasses the entire spectrum of aerodynamic and aerothermodynamic phenomena which may be encountered by aircraft and aerospace vehicles from subsonic to hypersonic speeds, including static and dynamic behavior, transient phenomena, maneuvering, stability and control, aerodynamic performance, real-gas effects, heat transfer, and combustion phenomena. Applications include both external and internal flow fields and multiple body interactions. This subtopic solicits proposals for novel approaches in any of the areas listed below. Only those proposals for innovations which significantly advance the state of the art will be considered for award. Proposals must clearly identify Phase II objectives and expected applications both in NASA programs and any potential commercial markets to which the research results could be directed.

- Numerical methods for solving fluid flow equations which increase computational efficiency, accuracy, speed and utility. These include construction of new algorithms, improved computer languages, improved boundary condition procedures, efficient grid-algorithm interfacing, applications of automation techniques, and other innovative techniques.
- Analytical and numerical techniques that enhance understanding of transition and turbulence phenomena and provide improved models for solving the Navier-Stokes equations.
- Grid generation procedures, unstructured grids, solution-adaptive procedures, and grid quality measures.
- Scientist's workbenches with integrated, graphical tools for interactive geometry definition, grid generation, flow visualization, and solution validation.
- Scientific visualization, including techniques to identify and visualize areas of complex flow physics.
- Related multi-disciplinary activities.

02.02 THEORETICAL AERODYNAMICS AND VISCOUS FLOW
Center: LaRC

The solutions to a broad spectrum of unsolved aerodynamic problems important to the design and analysis of advanced aircraft configurations will require greater theoretical understanding of boundary layers, free-shear layers, recirculating vortex flows, and practical means of improving flow quality in critical areas and under actual flight conditions. This subtopic solicits proposals for research on innovative new concepts and original analytical or experimental approaches which offer new insights to specific phenomena such as, but not necessarily limited to, those listed below.

- Accurate prediction of compressible three-dimensional boundary layer stability.
- Laminar to turbulent flow transition.
- Theoretical studies of chaos leading to understanding of its relation to fluid dynamic turbulence.
- Theories of and practical techniques for turbulence management and control, including skin friction reduction.
- The physics of and structure of turbulent shear flows and high-speed shear layers.

02.03 HYPERSONIC VEHICLE AEROTHERMODYNAMICS
Center: LaRC

This subtopic concerns aerothermodynamic phenomena associated with the design and development of future hypersonic aerospace vehicles such as a second-generation shuttle, aeroassist space transfer vehicles, the National Aero-Space Plane and future hypersonic transport aircraft. These phenomena may also be applicable to reentry vehicles and future planetary probes. Proposals are solicited for research on innovations aimed at achieving increased understanding, developing prediction techniques, and providing experimental verification in the areas included in but not limited to the following listing:

- Adding real gas physics to existing and future numerical schemes.

- Gas-surface, interactions, chemical energy accommodation, and surface catalytic reaction rates.

- Radiation and rates associated with excitation of radiation.

- Equilibrium and finite-rate chemistry.

- Transport properties and multi-component mixing laws.

- Chemical kinetic rates.

- Turbulence modeling and simulation.

- Experiments to guide the development and verification of CFD models of physical phenomena.

- Grid generation techniques for complex hypersonic/reentry vehicles.

- High velocity and high-temperature experimental techniques, including methodology for radiative and non-equilibrium flows and non-intrusive flow measurement techniques.

- High-order algorithms for performing unsteady simulations of transition and turbulence.

- High-order algorithms for computing shock-boundary layer and shock-turbulence interactions.

02.04 RAREFIED GAS DYNAMICS
Center: MSFC

Improved prediction techniques are needed to solve numerous important rarefied gas dynamics problems for space vehicles including predicting aerodynamic and aerothermal characteristics for aerobraking space transfer vehicles, spacecraft orbital aerodynamic characteristics, on-orbit reaction control thruster vacuum plumes, and plume-induced effects in space such as thrust reduction, and impingement heating and contamination on spacecraft or large orbital structures. This subtopic solicits proposals for research on innovations to achieve any of the objectives listed below not included within Subtopic 02.05.

- New techniques for defining transition flow regime aerodynamic characteristics, and free molecule flow surface interaction effects.

- Inclusion of radiation production and transfer from weakly ionized gases in Monte Carlo flowfield simulations.

- Rarefied flow heating prediction methods for surface irregularities (tile gaps, fabric TPS joints, etc.)

- Prediction of low density blunt face heating distributions which include variable chemistry effects, viscous layer effects, and wall slip boundary condition effects.

- Three-dimensional rarefied stagnation line solution techniques with finite rate chemistry, multicomponent diffusion, and electric field effects for rapid engineering calculations.

- Extension of continuum blunt body problem formulations to more accurately include finite thickness shock layer physics.

- Innovative methods to predict catalytic effects of aerobrake TPS material in non-equilibrium flow at high altitudes.

02.05 PLUME-INDUCED EFFECTS ON LAUNCH AND ORBITAL VEHICLES
Center: MSFC

Accurate prediction techniques and measurement methods are required for base convective and radiation heating, plume impingement heating, and plume induced aerodynamic effects to axisymmetric and three-dimensional multi-engine plumes. This subtopic solicits proposals which offer innovative conceptual ideas and original analytical methods for new or improved prediction techniques (and experimental verifications) which are clearly superior to present capabilities, and which include, but are not limited to, the following:

- Infrared radiation codes to characterize solid rocket motor plumes, facilitating the modeling of complex vehicle geometries and prediction of incident radiation at critical body point locations in the vehicle base region.

- Nozzle plume computer codes which properly model solid-rocket-motor particle subcooling and freezing.

- Methods to determine the infrared optical properties of particles in plumes.

- Multi-engine prediction methodology for plume-induced environments.

- Recirculation plume gas modeling for defining the base gas temperature, surface pressures, and heating rates.

- Vent area/nozzle spacing mass balance analysis techniques.

- Improved short-duration hot-flow testing techniques for plume launch vehicle aerodynamic effects and heat transfer.

- Plume impingement during launch and staging.

- Fully viscous on-orbit, reaction-control-system nozzle and plume flowfield definition methods which include non-equilibrium processes in the transitional flow regime of low density plumes.

- Accurate and efficient procedures to predict plume impingement pressures, heating, and contamination effects on surfaces of orbital spacecraft.

- Plume and external flow interaction during launch vehicle abort scenarios including return to launch site.

- Experimental techniques to obtain low-density plume and plume-impingement environments to support model development.

- Experiments to simulate on-orbit liquid and gas venting.

02.06 CONFIGURATIONAL AERODYNAMICS INCLUDING VORTICES
Center: ARC

The development of experimental methods and data analysis procedures to enhance the understanding of vortex-dominated flows would have important uses in boundary layer management, high angle-of-attack aerodynamics, separated flows, rotor wake interactions, and vane-type vortex generators. Innovative experimental techniques using small-scale, laboratory-size facilities are needed to understand the interaction between vortices and boundary layers, shear layers, or solid surfaces. The extensive use of modern sensor technology and/or sophisticated computer-experiment integration is considered an important part of this area of interest.

This subtopic solicits proposals of innovative concepts and techniques related to new and improved aerodynamic configurations for aircraft, including but not limited to the following areas:

- Vortex-flow, control devices, and wing configurations to improve body-wing-strake and slender wing performance.

- Nozzle-afterbody and inlet integration.

- A new approach for solving three-dimensional aircraft configuration aerodynamic problems using the Euler and Navier-Stokes equations that does not rely on well-structured, body-fitted coordinate systems.

- Expeditious methods for handling the extremely large amounts of data produced in experimental and computational research on aircraft configurations. Special visualization techniques are required and may need development of specialized software and hardware.

02.07 ROTORCRAFT AERODYNAMICS AND DYNAMICS
Center: ARC

Many aspects of rotorcraft aerodynamics and dynamics are not thoroughly understood or adequately modeled. Examples of importance include: aerodynamics of rotor-airframe-tail interactions; rotor-blade, air-flow loading analyses; improved rotor system performance; analysis of advanced hub designs and their influence on rotor dynamics; rotorcraft vibration and vibration alleviation; aeroelastic stability; rotor noise; and new rotor concepts for high speed flight.

This subtopic solicits proposals for the development of innovative methods to produce greater understanding of the basic phenomena involved in these areas and greater knowledge of their detailed characteristics. Advances are needed to permit well-verified accurate predictions to be made for current rotorcraft

configurations including applications to tilt-rotors, single main rotor and tandem helicopters, and co-axial helicopters and for helping to define next-generation high speed rotorcraft, specifically, rotorcraft vehicles with relatively low disk loading and the efficient low speed attributes of a helicopter but with a high speed cruise capability of 300-450 knots.

Offerors should emphasize novel concepts and innovative analytical or experimental approaches to the development of any proposed concept. Evidence of substantial prior analytical or experimental basis for the proposed innovation and clear explanations of how any innovation differs from known concepts should be included.

02.08 WIND TUNNEL DESIGN AND EXPERIMENTAL TECHNIQUES
Center: LaRC

Improved wind tunnel designs and techniques are required to advance understanding of aerodynamic phenomena. This subtopic solicits proposals for innovations to increase the capabilities and value of wind tunnel investigations. Areas of interest include but are not limited to the following:

- Propulsion simulators for operation in a cryogenic transonic wind tunnel over the temperature range of 150 °F to −300 °F as needed. This simulator should be sized for a model whose half span is approximately 5 feet.
- Test section designs for transonic wind tunnels to reduce wall interference, reduce power requirements, and improve flow quality.
- Methods to suppress noise and turbulence caused by flow disturbances in wind tunnels.
- Methods to tailor the interacting forebody and wing vortex flows occurring on aircraft at high angles of attack in order to reduce vertical stabilizer buffet. Consideration should be given to innovative methods for decoupling the forebody and wing primary vortices by mechanical means to improve the flow environment in the vicinity of twin vertical stabilizers.

02.09 WIND TUNNEL INSTRUMENTATION
Center: LaRC

This subtopic solicits proposals for innovative wind tunnel instrumentation to increase the range, accuracy and utility of experimental investigations. Specific areas of interest include but are not limited to those listed below.

- Miniature, smart, multichannel sensors for pressure in the range of 1 to 100 psi at temperatures from 100 K to 1000 K.
- Miniature sensors for temperature and heat flux measurements in the range 1500 °C to 3000 °C.
- Infrared optical fibers for image relay from target to infrared imagers in the 2 to 5μm and/or 8 to 12 5μm ranges.
- Non-intrusive measurement of model angle of attack and deformation.
- Measurement of high level strains at temperatures above 1100 °C.
- Direct measurement of skin friction in high temperature (1000 °C) environment.
- Spectroscopic quantitative monitoring of flow field parameters
- Flow field visualization in boundary layers.
- Polarization-preserving fiberoptic sensor systems for high temperature environments.
- In-situ measurement of gas composition and density profiles in the boundary layer or shock layer using instrumentation mounted in the model.
- Automated on-line analyses of unsteady pressure data to provide boundary layer transition location.

02.10 AIRCRAFT NOISE PREDICTION AND REDUCTION
Center: LaRC

Technology for better controlling noise and associated acoustic loads is needed for developing acceptable aircraft and rotorcraft. Advancement of this technology requires understanding of fundamental noise source mechanisms, propagation paths, and response of receivers. Sources of noise and acoustic loads

include: jet exhaust plumes, rotors, propellers, boundary layers, and turbulent flow and aerodynamic surface interactions. Propagation paths include inhomogeneous atmosphere and aircraft and engine structures. Receivers can be either people or aircraft and engine structures. In addition to the fundamental understanding of the source, path, and receiver, improved prediction methods and control/reduction concepts are needed. This subtopic solicits proposals for research on innovations in areas noted below related to noise generation, propagation, prediction and reduction which are needed to provide enabling technology for quieter aircraft and rotorcraft.

- Fundamental and applied CFD techniques for aeroacoustic analysis.
- Reduction concepts and prediction methods for noise radiation and associated acoustic loads of supersonic jet plumes.
- Reduction concepts and prediction methods for high-frequency fluctuating pressure loads on airframes and engine structures of supersonic and hypersonic aircraft.
- High frequency dynamic response and sonic fatigue characteristics of advanced light-weight structures to acoustic loads at elevated temperatures.
- Concepts for active or passive interior noise control for aerospace vehicles.
- Reduction concepts and prediction methods for rotorcraft and advanced propeller aerodynamic noise.
- Methods for predicting and assessing the sonic boom impact of supersonic transports.
- Methods for predicting acoustic propagation through atmosphere including the ground effects.

02.11 PROPULSION NOISE REDUCTION
Center: LeRC

A wide range of future aircraft types must employ low-noise, highly efficient propulsion system designs at subsonic, transonic or supersonic flight speeds. This subtopic solicits proposals for research on innovations for any of the objectives listed below. New design approaches for quieter advanced propulsion systems and components (including associated inlets and nozzles) must be supported by analytical and experimental verification methods.

- Aerodynamic and acoustic analysis and design methods and diagnostic or flow visualization methods, including unsteady flows.
- Reduced noise generation with increased efficiency, greater strength, and lower weight.
- Prediction of the steady and unsteady aerodynamics and acoustics of unducted and ducted propellers (ultra high bypass ratio fans) at both design and off-design conditions.
- Advanced low-noise propeller configurations which make higher subsonic cruising speeds possible.
- Practical and efficient jet and supersonic-fan source noise reduction concepts for supersonic civil transports which permit federal and local community noise rules to be met with maximum efficiency.

03.00 AIRCRAFT SYSTEMS, SUBSYSTEMS, AND OPERATIONS

03.01 AIRCRAFT ICE PROTECTION SYSTEMS
Center: LeRC

Improved aircraft icing protection remains an important aviation safety objective. This subtopic solicits proposals for innovative concepts and analysis methods which will lead to highly effective and efficient ice protection systems and techniques for helicopters, general aviation aircraft, commercial transports, and military aircraft. Areas in which innovations are sought include:

- Methods that aid in winter operation safety, particularly in-flight ice protection systems that minimize weight and power consumption, and ground deicing and anti-icing fluids that minimize aerodynamic penalties and maximize holdover times.

- Novel experimental techniques that can be conducted in a realistic icing environment, e.g., methods for flow visualization, cloud droplet characterization, droplet trajectory measurements, ice-accretion geometric characterization, ice-accretion aerodynamic penalties measurement, and icing scaling laws for wind tunnel and flight testing.

- Non-intrusive instrumentation to detect and measure ice accretion and supercooled cloud properties. Special emphasis should be placed on taking into account realistic aircraft icing situations.

- Methods to predict ice accretion on aircraft components and the resultant change in aerodynamic performance.

- Methods to predict aircraft performance and handling chacteristics in the icing environment during takeoff, landing, and cruising.

03.02 AIRCRAFT SEVERE WEATHER ENVIRONMENT
Center: LaRC

This subtopic solicits proposals for innovations to minimize aircraft flight hazards associated with severe weather by improving predictability, detection, and avoidance of severe storm hazards and by providing a database for safe design criteria for unavoidable hazards. Hazards considered here are heavy rain, winds, wind shear, turbulence, and lightning. Innovative improvements are needed in airborne equipment suitable for measuring environmental effects and in algorithms for alerting the pilot and crew of impending changes in weather and flight hazard conditions described below.

- Innovations are needed for assessing the effects of lightning on future advanced composite aircraft employing flight critical digital systems. Refined lightning characterization requires lightning/aircraft interaction models; techniques and methodology for interpretation and generalization of data for prediction of lightning/aircraft interactions methodology and direct strike data; and techniques for predicting lightning-induced effects on systems in advanced composite aircraft.

- Novel airborne sensors for the premonitory detection of low-altitude wind shear are needed. Many microbursts are known to contain water droplets; therefore, conventional radar techniques may be useful for handling this problem. Radar designs must cope with the suppression of ground clutter effects, the achievement of adequate spatial resolution, and the recognition of an unambiguous, quantitative "signature" associated with the shear phenomenon.

- Innovative concepts for an airborne weather monitoring and processing system that will accept data from various sensor units (airborne and groundbased) to provide hazardous weather information to the pilot.

03.03 CONTROL CONCEPTS FOR FIXED WING AIRCRAFT
Center: LaRC

Modern aircraft design concepts rely heavily on advanced controls techniques to enhance mission performance and efficiency, and to expand flight envelopes. Flight profiles must be carefully tailored and controlled to avoid limits imposed by aerodynamic, heating, structural, and propulsion considerations to achieve a broad range of mission objectives. Interactions between disciplines are at unprecedented levels and the use of numerous control effectors and thrust-vectored propulsive concepts requires complex flight control systems. Current and future aircraft mission requirements require that conventional control system design criteria be re-examined and improved synthesis methods be developed for highly integrated multidisciplinary dynamic systems. A key challenge will be to provide the proper interface between the airframe, the guidance and control systems, the pilot, and the exterior situation.

This subtopic solicits proposals for innovative advances to the technologies involved, with emphasis on any of the areas listed below.

- Guidance laws and concepts including trajectory optimization.

- Readily implementable, full-envelope, control-law design algorithms.

- Pilot-vehicle interface techniques.

- Utilization of knowledge-based, expert systems concepts.

- Control system design and aircraft performance metrics.
- Reliable onboard aircraft state estimation.
- System identification and parameter extraction.

03.04 FULLY AUTOMATIC GUIDANCE FOR ROTORCRAFT
Center: ARC

Nap-of-the-earth (NOE) flight in a conventional helicopter is currently extremely taxing for two pilots under visual flight rule conditions. Developing a single-pilot all-weather NOE capability will require significant automation. A major goal would be the development of pilot-centered computer/sensor aiding concepts for enhanced NOE flight-control capability. The NOE flight regime requires the helicopter to fly below tree tops whenever possible, following a preplanned nominal trajectory. This subtopic solicits proposals for innovative problem solutions in the following two areas:

- Range sensors for local navigation and guidance

  The ability to estimate range to objects in the proximity of a moving vehicle is essential to the guidance of a helicopter flying at low altitude. It may be necessary to integrate range information from more than one sensor to acquire range over a large field of view. Innovative approaches are sought for the development and integration of a low cost sensor system, active or passive, which can be installed in a helicopter.

- Neural networks for rotorcraft guidance and control

  The two key features of neural networks are adaptability and parallelism. These two properties promise networks that can be trained to make decisions at high speed and in a robust manner. Neural networks have been advocated as effective means of solving problems in machine vision and robotics. The emphasis would be on innovative applications of neural network technology to the special needs of automatic NOE flight, specifically, to perform range estimation and guidance to assure a safe flight among obstacles.

03.05 FLIGHT RESEARCH SENSORS AND INSTRUMENTATION
Center: ARC

Real-time measurement techniques are needed to acquire aerodynamic, structural, and propulsion system performance characteristics in flight and to expand the flight envelope of aerospace vehicles safely. Flight regimes of interest include subsonic, supersonic, and hypersonic.

This Subtopic solicits proposals for innovative airborne sensors and instrument systems for aircraft and small rocket launched flight research payloads which are superior to current practice. Requirements include fast response, low power, low volume, minimally intrusive concepts having high accuracy and reliability. Phenomena and parameters of interest include:

- Turbulence up to Mach 0.8.
- Boundary layer flows using visualization.
- Various instability modes affecting boundary layer transition and separation.
- Transition frequency components of turbulence in the boundary layer in hypersonic flight.
- Surface acoustics employing optical technology.
- Off-surface flow fields suitable for CFD code validation for regions from the surface to 50 feet off the surface, including vortical and separated flow.
- Large-angle flow direction and velocity, with long life, low maintenance, and extreme humidity capabilities.
- Freestream ambient temperature, pressure, density, flow angles, and speed from subsonic through transonic, supersonic, and/or hypersonic speeds.
- Angle-of-attack within 0.1 degree from Mach 4 to Mach 15.
- Electric fields aloft.
- Strain on advanced structures at 1700 °C and above.

- Structural deflections from Mach 3 to Mach 20, using optical methods.

- Ice detection in the freestream.

03.06 AIRCRAFT FLIGHT TESTING TECHNIQUES
Center: ARC

Improved flight test data acquisition and analysis methods using onboard and/or ground-based real-time processing are needed. This subtopic solicits proposals for innovative techniques to obtain any of the following types of information:

- Accurate structural modes.

- In-flight thrust for advanced turbojet or turboprop engines.

- Several simultaneous aircraft performance parameters, such as lift and drag at extreme angle of attack (greater than 50 degrees), during integrated maneuvers.

- Nonlinear characteristics of aircraft and propulsion systems such as longitudinal and lateral directional aerodynamics and inlet flow at elevated angles of attack.

- Real-time monitoring and control using expert systems applications.

- Local flow visualization and characterization to locate vortex flows and laminar-to-turbulent flow transition in a wide variety of flight conditions.

03.07 HYPERSONIC FLIGHT SYSTEMS TECHNOLOGY
Center: LaRC

Concepts for combined cycle engines, airframe-engine integration, lightweight structures, cryogenic, and high temperature insulations and subsystems are emerging which may produce the necessary dry-weight fraction and propulsive and aerodynamic performances needed for aircraft flying at more than 5 times the speed of sound. This subtopic solicits proposals for innovative systems-oriented research to support and enable the use of advanced, high priority hypersonic technologies. Areas of interest are listed below. Proposals for innovation research in the supporting technical disciplines which are invited in other topics in this solicitation, e.g., Topics 1, 2, and 4, will not be considered in this subtopic. Areas of interest include:

- System optimization methods applicable to optimizing the configuration, propulsion system, aerodynamics, thermal management system, trajectories, and dry weight.

- Vehicle sizing and scaling algorithms.

- Computer-aided design software applicable to the design of hypersonic aircraft at the conceptual level.

- Specific technological objectives for endothermic fuels.

- Advanced propulsion cycles applicable from Mach 0 to 5 or 6 and accompanying design and integration techniques.

- Advanced heat-rejection radiators, compact, high-performance connective heat exchangers and cooling panels, and cooling jackets that simultaneously employ regenerative and transpiration cooling.

- Durable coatings that can significantly reduce the aerothermal heat load to external/internal surfaces.

03.08 VERY-HIGH ALTITUDE AIRCRAFT TECHNOLOGY
Center: ARC

This subtopic solicits proposals for research to enable the development of subsonic aircraft for sustained flight above 100,000 feet altitude. The physical properties of the atmosphere change quickly with altitude beyond 80,000 feet, and atmospheric flight at such extreme altitudes currently poses significant challenges in all aerospace technologies. NASA currently has no subsonic flight capability above 70,000 feet.

NASA's current interest involves a high-subsonic speed atmospheric sampling aircraft capable of at least three hours endurance at altitude with a 1,000 lb. payload, manned or unmanned. Specific areas of interest for this subtopic include aerodynamics; propulsion; structures and materials; guidance, control, and navigation; aeroelastic flight dynamics; and other technologies related to flight at extreme altitudes. The results sought are design-oriented solutions to specific problems or design tools. Proposals for studies involving the development of specific design

configurations are not of interest unless they are to determine the feasibility of innovative concepts that have not been previously investigated in the open literature.

03.09 AERONAUTICAL HUMAN FACTORS AND FLIGHT MANAGEMENT SYSTEMS
Center: ARC

Rapid developments in microprocessor technology and electronic display systems have made it feasible to automate many flight crew functions. An important objective is to keep the crew properly involved in the flight management process as their role moves from that of an operator of the system to that of a manager of the system. This subtopic solicits proposals for innovations which will enable that objective to be achieved. Specific areas of interest are listed below. Considerations in each area should include the automation environment, crew information processing and decision making, and the associated cognitive workload.

- Control and display operational concepts and crew-system interfaces involving cockpit displays of flight management information that will ensure the efficient and safe use of ATC system technology.

- Electronic control and display technology for consolidating and integrating the man-machine interface, including electronic display media, pictorial multimode display generation, and multifunction controls.

- Systems that monitor status and inform, advise, or aid the flight crew and other advanced input and output devices and methods such as voice synthesis and recognition, pointing, and touch devices.

- Flight path planning and replanning and communication aids to facilitate safe and efficient flight operations.

- Human response measurement technologies for a broad range of human functions including assessment of crew workload and situation awareness.

03.10 DEVELOPMENT, TESTING AND VERIFICATION OF FLIGHT CRITICAL SYSTEMS
Center: ARC

Integrated computer-aided techniques for the development, testing, implementation, and verification of flight-critical systems are needed for future research and operational aircraft. These aircraft will rely on both conventional and knowledge-based systems for correct and safe operation. The complexity of such systems requires that techniques for integrated system, control law, display, and functional specifications must be developed, documented, implemented and tested. This subtopic solicits proposals for innovative computer-aided systems that:

- Provide better support of life cycle requirements through functional specification, design, implementation, testing and maintenance.

- Allow more effective automatic testing and verification of conventional and intelligent knowledge-based systems.

- Improve human-readable documentation for design, implementation, and testing.

03.11 INTEGRATED AEROSPACE VEHICLE FLIGHT CHARACTERISTICS SIMULATION
Center: ARC

More rapid, accurate and reliable methods for predicting flight characteristics of advanced aerospacecraft are needed for design, for interpreting flight test results, and for ensuring safety during flight envelope expansion. In particular, accurate predictions of aeroelastic and aeroservoelastic stability parameters involving interactions among numerous system characteristics, e.g., structures, aerodynamics, and control systems, are essential.

This subtopic solicits proposals for novel, innovative multi-disciplinary non-linear systems simulation techniques for advanced aerospace vehicles. Projects are expected to yield improved design tools to accomplish some of the objectives listed below, applicable to designs of advanced vehicles including the National Aero Space Plane (NASP).

- Prediction of pressure and thermal load distributions on the aerospacecraft surfaces, or similar distributions due to propulsive forces, by employing accurate CFD techniques.

- Effective numerical algorithms for multidisciplinary systems response analysis with possible adaptive grid generation at selected time steps.

- Automated three-dimensional mesh generation techniques.

- Use of high performance computing machines for integrated systems analysis.

04.00 MATERIALS AND STRUCTURES

04.01 HIGH TEMPERATURE COMPOSITE MATERIALS TECHNOLOGY FOR AEROPROPULSION APPLICATIONS
Center: LeRC

High-temperature structural composites which can be tailored to specified design requirements are important candidates for application in aerospace propulsion structures. This subtopic solicits proposals for innovations which will help make these applications possible. Areas of interest include:

- Test procedures to determine fiber properties at room, cryogenic, and high temperatures including time and nonlinear stress effects. Properties include physical, thermal, mechanical, electrical, and magnetic characteristics in both the longitudinal and transverse directions.

- Unique computational methods (other than conventional approaches) using appropriate material characteristics and structural and loading parameters to predict fracture toughness in high-temperature composite structures.

- Adapting composite mechanics methods (micro, macro, fatigue, life) for simultaneous calculations on multi-parallel processing computers to permit the design of composite structures to be made in one pass through the multi-parallel processor.

- Dedicated systems to be located on board for continuously monitoring in-service life/durability of fiber composites in critical structural areas. Systems must be sufficiently sensitive to detect, nondestructively, degradation in both stiffness and strength, and must be able to accommodate deviations by real time probabilistic analysis and statistical inference.

- Coupled multi-disciplinary formulations to be used for the development of specialty finite elements to solve these types of problems. The formulations must be based on fundamental concepts and respective primitive equations. The disciplines of interest include: structural mechanics, fluid mechanics, heat transfer, material science and other closely related disciplines. The specialty finite elements must be suitable for embedding in general purpose computer programs.

04.02 PROCESSING OF HIGH TEMPERATURE COMPOSITE MATERIALS FOR AEROPROPULSION SYSTEMS
Center: LeRC

A deterrent to the widespread use of high temperature composites in aeropropulsion applications is low and/or variable properties due to flawed microstructures. This is particularly true for intermetallic composites and ceramic composites. The nature of the flawed microstructures varies widely; e.g., pores, cracks, undesirable phases, inhomogeneities in grain size, phase distribution and/or fiber distribution, damaged fibers, reacted fibers, uncontrolled fiber/matrix interface quality, contaminated surfaces. It is important that methods be developed to improve consolidation processing control such that these flawed microstructural features can be eliminated or minimized.

This subtopic solicits proposals for new, imaginative, and innovative approaches to composite consolidation and/or subsequent processing techniques to produce intermetallic and ceramic matrix composites of dramatically improved quality and homogeneity.

04.03 IMPROVED FIBERS FOR HIGH TEMPERATURE COMPOSITES FOR POWER AND PROPULSION
Center: LeRC

Viable composite materials are needed to advance technologies for high-temperature energy conversion systems in aeropropulsion (high thrust-to-weight gas turbines), space propulsion (space shuttle main engine components) and space power (solar dynamic and nuclear thermal). The ultimate realization of high-temperature, composite materials depends strongly upon the availability of high quality reinforcing fibers that do not exist today. New fibers are needed for all three classes of high-temperature matrix materials, i.e., metals (e.g., Cu and Nb), intermetallics, (e.g., Ni, Fe, and Ti aluminides) and ceramics (carbides, nitrides and oxides).

This subtopic solicits proposals for innovative synthesis and processing approaches to yield continuous fibers that offer significant improvements over current state-of-the-art fibers such as SiC and W. Fiber property improvements required are lower density, higher strength at elevated temperatures, higher elastic modulus, higher creep resistance, better environmental resistance, better thermal stability, better matrix compatibility (chemical and thermal strain) and easier handling. Innovative fiber coatings that will ameliorate compatibility problems (environmental, chemical and thermal strain), are also considered an integral part of the need for improved fibers.

04.04 ENVIRONMENT-RESISTANT ALLOYS FOR LAUNCH VEHICLE AND SPACE PROPULSION SYSTEMS
Center: MSFC

Hydrogen embrittlement and oxygen compatibility impose severe restrictions on the use of many alloys in advanced propulsion systems. Protective coatings, weld overlays, and usage limitations are often employed to minimize or impede environmental effects. The prohibition of many alloys and the significant costs associated with characterizing materials under exotic conditions increase initial and life cycle costs of propulsion systems. Proposals for innovations are solicited that will bring improvements in the following areas:

- Thermodynamic and metallurgical modeling techniques for the prediction of environmental effects on present and experimental alloys. The mathematical projections based on the model would be used as a precursor to mechanical testing of proposed alloys. Microstructural constituents, phase stability, and composition would be essential components of the model.

- Advanced, non-intrusive, coating methods and materials for the protection of alloys from environmental effects. Existing protective coatings and application methods lack the mechanical strength to withstand high centrifugal loading, are difficult to apply to complex geometries, and are extremely subject to damage. Composition gradient sputtering, ion implantation, and shot peening technologies should be explored.

- Development of novel thermal and mechanical processing schedules to optimize existing and experimental alloys for improved resistance to environmental effects.

04.05 COMPUTATIONAL STRUCTURAL METHODS FOR AEROPROPULSION APPLICATIONS
Center: LeRC

Computer simulation of the complex structural interactions which occur within the hostile thermomechanical loading environment of aerospace propulsion machinery is an extremely demanding computational problem. Many reanalyses can result in extreme demands on computer resources or require drastic simplifications of the analysis model. Advances in computer science and technology are providing new capabilities which will allow very costly experimental system development to be replaced with numerical simulation. Multiprocessor computer architectures provide opportunities to improve the formal optimization and probabilistic design methods required for this technology.

This subtopic solicits proposals for novel, innovative techniques which exploit emerging computing hardware architectural concepts, or convert existing capabilities in making use of these new computer systems, in achieving any of the following objectives:

- Improve aeropropulsion structural analyses and develop advanced methods for analysis

and design optimization; determine how applicable and adaptable a particular computer architecture is for solving specific aeropropulsion structural analysis and optimization problems; and determine the ability of new methods and computer hardware such as neural net technology to replace the need for many re-analyses.

- Exploit new machine architecture to solve problems in aeropropulsion system structures which often have cyclical symmetry, often have nonlinear response, are subjected to high temperatures, operate with high speed rotations, and exhibit fluid-structure coupled response. The formulation and solution of these problems exploiting new machine architectures is needed.

04.06 COMPOSITE MATERIALS FOR AEROSTRUCTURES AND SPACE APPLICATIONS

Center: LaRC

This subtopic solicits proposals for innovations in resin-matrix, metal-matrix, and carbon-carbon composite materials which offer significant structural weight savings and enhanced performance in airframes and spacecraft structures.

- Aircraft resin-matrix composites with higher structural efficiency, reduced costs, and greater long-term, high-temperature performance including: damage-tolerant fiber architectures using textile processes; new loom/machine concepts to produce multiaxial, multilayer fiber architectures; cost effective processing and automated fabrication methods, new materials, and material forms; models and sensors for in situ cure monitoring.

- Carbon-carbon composites for greater oxidation resistance of hot structures on advanced hypersonic vehicles including: thin, moisture-resistant coatings; improved coating adherence; durable sealants; improved interlaminar properties; efficient fabrication methods.

- Composites (both polymeric and metal-matrix) for ultra high-performance spacecraft structures including: precision thin-gage tubes; fabrication processes which minimize residual stresses and distortions at low temperatures; remotely-rigidized materials for on-orbit deployment of space structures; new methods to fabricate glass-matrix composites.

- Metal-matrix composites for high-temperature applications including: thermally stable fiber/matrix interface; low-cost fabrication techniques; new high-strength, high-temperature fibers.

- Mechanics-based composite mathematical models to describe deformation, strength, and life are required as tools to support structural design and analysis: models relating fiber architecture to local stress states in textile forms such as braids and weaves; models relating interaction of temperature, environment, and mechanical loads to long-term structural integrity at elevated temperature including prediction methodology and accelerated test procedures to extrapolate short-term experimental data to long-term applications.

04.07 LIGHT ALLOY METALLICS FOR AIRFRAME STRUCTURES

Center: LaRC

Future aerospace vehicles will require higher structural efficiencies than currently possible with available metallics, including light alloy systems. Improvements in structural efficiencies may be attainable through innovative structural concepts, processing methods and new alloy products with significantly improved properties. Innovative approaches are sought to achieve the following objectives:

- Exploitation of rapid solidification technology, powder metallurgy processing, and mechanical alloying which have all resulted in laboratory quantities of materials with dramatically improved properties, to produce new materials of non-equilibrium chemistries which will increase the upper use temperature for each principal alloy system (beryllium, aluminum, titanium) by at least 200 °F. Materials should be amenable to processing to foil gage thickness as well as conventional product forms of extrusion, forging, plate, or sheet.

- Advanced materials such as intermetallic compounds of binary alloys, which have unique characteristics and properties would, if producible, be useful for applications in various thermal protection systems and airframe surfaces of hypersonic vehicles. These materials are usually difficult to produce and form in usable structures.

- Mechanics-based mathematical models that describe the deformation, strength, and life of these materials are required as tools to support structural design and analysis. Approaches are needed to develop models that will facilitate the computational design of new material systems. This will include innovative approaches to establishing direct cause-and-effect relationships between features of the material's microstructure and the macro-scale mechanical properties.

04.08 WELDING TECHNOLOGY
Center: MSFC

This subtopic solicits proposals for innovative techniques to control and improve the properties of weldments and achieve lower cost, lighter, more reliable components. Of interest are:

- On-orbit repairs and metal joining:
  - compatibility with space environments;
  - remote and/or autonomous control of welding process;
  - unique joint designs;
  - quality assurance methods;
  - assembly techniques and constraints, including effects of distortion;
  - tooling and fixturing techniques;
  - cutting and joint preparation techniques;
  - space welding test and simulation facilities.

- Mathematical models for optimizing process-design and setup parameters and for use as a software component of real-time control systems. Processes for manufacturing critical aerospace hardware or for on-orbit applications are of interest. Physically based models are considered more informative and trustworthy than purely empirical correlations, but both models are of potential interest. Methods for testing and correlating the models to test results must be included.

04.09 NONDESTRUCTIVE EVALUATION TECHNOLOGY TO CHARACTERIZE MATERIAL PROPERTIES
Center: LaRC

Proposals for innovations are solicited for characterizing material properties using nondestructive evaluation (NDE) techniques. Traditionally, NDE has been a final checkout procedure for quality assurance. Today, the needs for NDE go far beyond flaw detection to fundamental quantitative measurements of material and microstructural properties. Such measurements are needed to provide data on real physical properties that can be evaluated to determine their effect on performance of the material or structure. Quantitative NDE should be applied at developmental phases of new materials as well as process phases of engineering materials. The desired benefits are improved safety, reliability, and economic advancement for various aerospace systems; reduced development time for introducing new materials and structures; reduced costs in developing and maintaining aerospace systems; and means to make informed decisions for safe and economical life extension of aging systems.

Proposals should involve novel technology and instrumentation to address the state of health of both space and aircraft systems in practical situations, including aging airfleet evaluation, and must focus on development of nondestructive probing energies to determine aerospace material properties related to their performance requirements. NDE opportunities include the development of measurement science instrumentation for characterizing new high-temperature materials; detecting and measuring surface contamination as it relates to adhesive bonding; effects of atmospheric and space environment of materials; effects of stress, fatigue, and corrosion; microstructural imaging and characterization; electronic materials NDE; and in-situ lifetime monitoring of current and future materials and structures.

04.10 BOND STRENGTH OF THERMAL SPRAYED COATINGS
Center: KSC

The increased use of metallic and ceramic thermal-sprayed coatings (TSC) in industrial and aerospace applications has resulted in the need for novel, innovative test methods to evaluate the bond strength in a manner which is representative of in-service conditions. The current ASTM test method (C633-79) loads the test specimen perpendicular to the plane of the TSC-substrate interface. Although the test method provides a usable quality control tool, it has significant limitations. Sample preparation is a time consuming operation; the bond strengths measured are limited to the strength of the adhesive used in sample preparation; and the results reportedly do not always correlate with in-service conditions.

This subtopic solicits proposals to develop innovative, accurate, and reliable bond-strength test methods which are easy to perform.

04.11 SPECIAL PURPOSE MATERIALS, PROCESSES, AND TESTING FOR SPACE FLIGHT APPLICATIONS
Center: GSFC

Innovative approaches are sought for new materials and processing techniques for use on research spacecraft. Areas of interest include but are not limited to the topics listed below.

- Tribological systems that will enhance spacecraft performance during scanning operations and not be susceptible to contamination problems.
- Low outgassing marking inks that can be applied by brush, spray, silk screen, or stamping and possess good chemical and abrasion resistance.
- Improved paints for spacecraft applications, in particular, a conductive, flat black for cryogenic applications is needed.
- Transparent, photo-elastic, thin-film materials that can be used for measuring and monitoring strain on structural member surfaces.
- Automated scanning and full-view NDE methods for measuring the size of cracks (in the range of 0.1 to 5.0-mm) at critical capture areas that have varied geometries.
- Low-outgassing, thread-locking compound with a range of shear strengths. The compound should be single component, possess long shelf life, and be easy to apply.
- Laminated printed circuit boards with tailored coefficient of thermal expansion to address thermal fatigue of solder joints which poses a serious problem to long term reliability of spaceflight electronics.
- Microcrack-resistant composites for high-precision reflector panels.

04.12 THERMAL PROTECTION MATERIALS AND SYSTEMS
Center: ARC

Future atmospheric entry vehicles, such as aerobraking orbital transfer, manned and unmanned planetary entry (Lunar and Mars vehicles), and transatmospheric vehicles, will require reusable thermal protection materials and ablative/reflective thermal protection materials systems which are more durable and lower weight than those currently available. This subtopic solicits proposals for innovative new concepts for new high- and low-density, rigid and flexible, ceramic materials and systems having extremely good thermal shock resistance and temperature capability to 1920 K.

Among the possible materials are Si_3N_4, SiC, BN, Al_2O_3, and other refractory carbides, nitrides, and borides. Possible forms are fiber/fiber composites, fiber/matrix composites, foams, and various woven forms developed into thermal protection system components for flexible thermal barriers, gap fillers, and high-temperature structural composites for application to future entry vehicles.

Ablative materials utilizing non-catalytic and radiation-reflecting technologies are required for planetary entry and return missions. To provide environmental durability, innovations are required for long-life waterproofing and increased toughness, in both materials and techniques, for future composite thermal protection materials as well as the state-of-the-art shuttle orbiter. New, minimum-weight, load-bearing and non-structural thermal protection systems utilizing the above components and new processing methods to form them are of interest.

04.13 ADAPTIVE DEPLOYABLE STRUCTURES
Center: JPL

Many future NASA missions will require large structures that deploy on orbit and will also impose very stringent dimensional accuracy and stability requirements on the structural system. The required dimensional accuracy and stability is on the order of one micron over a distance of twenty meters. Typical deployable structures require numerous rotational joints which inherently limit the dimensional accuracy of the structure. New concepts in structural and mechanical design, i.e. adaptive deployable structures, are required to enable future structures to meet

mission requirements. These new concepts will require new mechanisms for deployment and an integrated structural design such that the required dimensional stability is achieved. An example of such an integrated system would be autonomous mechanisms operating in conjunction with active structural members to provide the required moments and forces during the deployment process as well as after deployment to adjust the deployed configuration of the structure.

This subtopic solicits proposals for innovative structural and mechanical concepts for adaptive deployable structures and the strategy for locating actuation devices for optimum performance and reliability.

04.14 SPACECRAFT STRUCTURES AND MECHANISMS
Center: JSC

Future space operations will benefit from innovations in structural configurations, materials development, space fabrication techniques, environmental protection, and remotely actuated mechanisms for assembly, capture, or manipulation of structures. Longer duration missions being planned will require more durable materials and improvements in environmental protection. Higher reentry velocities will require structures and lightweight thermal protection materials that can withstand higher temperatures. In addition to numerous material innovations solicited in other subtopics, this subtopic solicits proposals for innovations including but not limited to the following:

- Lightweight shielding schemes for minimizing damage due to debris impact.
- Structures, joints, and mechanisms that can simplify fabrication, deployment, or assembly of structures in space.
- Unique landing or docking impact attenuation materials and mechanisms.

04.15 HIGH TEMPERATURE SUPERCONDUCTORS FOR AEROSPACE APPLICATIONS
Center: JPL
Center: LeRC

High-temperature superconducting materials may offer significant benefits for various aerospace technologies and applications. The result could be significant mass and cost savings and major enhancements in power generation and processing, propulsion, communications, and spacecraft subsystems. Specific applications may include large capacity energy storage systems with low mass-to-energy ratios, efficient energy conversion in ac and dc rotating machines, and efficient electric power transmission. Other potential uses could be for active and passive electromagnetic shields, on-board systems for interaction with planetary and solar B-fields (torque shielding), long-life, low-gravity refrigeration and cooling systems, and high magnetic energy and field configurations (solenoidal, toroidal, monolithic rings) for unusual applications such as magnets for magnetic suspension balance systems.

These beneficial applications of high-temperature superconductors will be achieved only if issues such as ceramic superconductor critical-current and magnetic-field capabilities and material stability can be resolved. Progress is required on issues such as material durability, stability and strength, and fabrication techniques. Improvements are required in critical current density and tolerance for magnetic fields, mechanical stress, and radiation.

This subtopic solicits proposals for innovations directed at the following:

- Fabrication of thin and thick films and bulk superconductors with improved electrical, magnetic, and mechanical properties required for the aerospace applications described herein. Examples of innovations include, but are not limited to: deposition techniques, single crystals in bulk or fiber form, compositions which enable high-field magnets, techniques for controlling bulk microstructure to achieve optimum properties, and fabrication methods for producing high T_c superconducting wires and busbars with high strength-to-mass ratio.
- New and innovative uses of superconductors in aerospace applications are also sought.

04.16 LUNAR MATERIALS UTILIZATION
Center: JSC

Eventual manned activities in space will require or be enhanced by utilization of lunar materials as sources of propellants, mass for shielding, volatile gases, metals, and ceramics or other construction materials. Proposals are

solicited for the development of innovative techniques and processes which may be carried out either on the lunar surface or in earth orbit. Selection of appropriate methods and equipment must consider reaction thermodynamics, reaction rates, engineering requirements, and system characteristics. Only those proposals whose development can be pursued on earth in the near future will be considered, and system studies and conventional engineering designs will not be acceptable. Specific areas of interest include:

- Novel methods for extracting oxygen, other useful gases, metals, and non-metals from lunar materials.
- Highly automated mechanical equipment, sized for the lunar or earth-orbital environments, to extract and move lunar materials from their source to the processing facilities, and to concentrate and size the feedstock to material which can be most efficiently used in the processing facilities.
- Simplified, self-contained systems that can process metallic or ceramic material into useful shapes including bars, rods, wires, bricks, paving blocks, or habitat structural elements.
- Novel systems for transporting lunar materials.
- Novel uses of indigenous materials at a lunar base.

Because prospects for ultimate direct applications of this research may not exist for many years, it is imperative that Phase I proposals must lead to realistic near-term Phase II objectives which will contribute significantly to ongoing NASA research programs and directly or indirectly provide expectations of non-NASA spin-off processes or products.

05.00 TELEOPERATORS AND ROBOTICS

05.01 LARGE SCALE TELEROBOTIC SYSTEMS
Center: LaRC

Telerobotic systems will be needed for space tasks, including assembly of large space structures, inspection, repair, and experiment operation. Innovative technology advances are sought in several areas which underlie all practical applications of large scale robotic operations:

- Sensing and Perception
  - Automatic or operator interactive systems for the generation of geometric data base by processing video/range images from a standard view;
  - Sensors and techniques for accurate determination of location and orientation of known objects (range less than 10m) for sensor based control or geometric data base verification applicable to the space environment.
- Manipulator Dynamics and Control
  - Modeling and control methods for multiple manipulator coordination, control algorithms for manipulators with redundant degrees of freedom, and analysis and ground simulation techniques for the evaluation of on-orbit assembly and manipulation of large space structures including scaling techniques, flexibility and compensation for 1-g test environment.
- Operator Interface
  - Efficient methods displays, and controls for monitoring, failure diagnoisis and correction of telerobotics systems performing complex assembly and servicing tasks;
  - Operator interactive systems for the development of task sequence planning and spatial path planning including methods of dealing with fault detection and diagnosis, and error recovery and replanning.

05.02 TELEROBOTIC AND BIOMECHANICAL SYSTEM SOFTWARE DEVELOPMENT
Center: GSFC

Systems containing teleoperator and autonomous robotic capabilities are envisioned for a wide range of challenging technological problems. For both ground and space based applications, there is an evolving need not only to model the machine part of a dynamic man-machine system but also the human biomechanical part. This envisioned analysis capability will be required to quantify alternative control scenarios from a human factors perspective, optimize machine controller design relative to human operator capabilities, and address such related issues as cumulative trauma, muscle stress, pain and fatigue. Innovative advances in the technology of generating an integrated control, structure, ergonomic, biomechanical system design and analysis capability are sought for the fully coupled dynamic system. Implementation concepts should maximize use of existing technology while including the following capabilities:

- Approaches for interfacing general purpose anthropometric and biomechanical models into comprehensive ergonomic models of the human operator during man-machine interaction.

- Systematic methodologies for dealing with:

  - anthropometric representations of static body segments;
  - ligament and musculotendon lines of action;
  - biomechanical representation of body segment motion;
  - generalized representation for multi-bone body segments;
  - generalized representation for diarthrosis, movable joints.

- Computationally efficient algorithms within the framework of the associated general purpose software implementation.

05.03 TELEROBOTIC ELECTRO/ MECHANICAL SYSTEMS
Center: GSFC

Systems combining teleoperation and robotic/autonomous features are envisioned for many future space applications, including unmanned science experiments, manufacturing, structural assembly, module replacement, and servicing and repair. Innovations in all areas of telerobotic technology are sought, including:

- Robotic Mechanisms/Motors/Actuators.

  - Manipulators that can function smoothly in near-zero gravity;
  - Compact, efficient high torque density motors, actuators and drives that are low-power, efficient, self braking and fail safe. Muscle-type actuators and controls suitable for multiple, independent tendon drives;
  - Micro-manipulators and controls for use on the end of space manipulators.

- End Effectors/Payload Fastening Devices.

  - End effector systems;
  - Ultra strong and compact low power fail-safe brakes;
  - Cableless power and signal transfer across the robot wrist joint;
  - Innovative payload fastening systems including the sensors and displays verifying proper attachment.

- Sensors.

  - Sensing and perception systems that permit real-time three-dimensional tracking of an end effector docking to objects. Representation methods of forces and torques for tele-operation;
  - Tactile, proximity, imaging (range and edge detection) and force and torque.

- Controls.

  - Innovative, robust algorithms to inhibit the excitation of systems resonances during high speed man in the loop control of flexible robotic systems;
  - Fiber optic-based end effector microcontrollers, digital-to-analog (D/A) and analog-to-digital (A/D) converters and multiplexers/demultiplexers, strain gauges and tactile sensors;
  - Calibration strategies and techniques for space manipulators. Simple, easy-to-use techniques for manipulator path planning using screen inputs.

05.04 SPACE BASED MANIPULATOR MECHANISMS AND CONTROLS
Center: JSC

Robotic systems are required to perform safely and reliably for a period of many years and must be capable of sustaining a failure while operating with a payload in close proximity to structure without an appreciable effect on operational performance. Space based manipulators generally have a very large payload mass to manipulator mass ratio capability, and have relatively flexible gearbox and boom structures configured for 6 and 7 degrees of freedom. Areas needing additional R&D:

- Fault tolerant mechanism that meets weight, power and minimum hardware requirements of space flight systems and the integration of control systems to minimize operational disturbances during an occurrence of a fault.
- Fault tolerant systems where two faults can occur serially at any level of command, control, sensing or actuation, with no erroneous operational effect. Innovative single fault tolerance concepts may be considered by NASA.
- Collision avoidance technique for the 57 foot, 7 DOF Space Station Remote Manipulator System which can operate in real time within a cluttered workspace and end effector rates not exceeding 1.2 feet per second. While vision processing systems and sensor fusion are not to be addressed here, fused sensor data would be imported into a limited world model for maintaining manipulator state and would be the source of objects for robot path planning. Collision avoidance technique must consider the path of the entire arm, not just the payload and/or end-effector. Determine and develop techniques which minimize Space Station computational resources.

05.05 ARTIFICIAL INTELLIGENCE FOR SPACE STATION APPLICATIONS
Center: JSC

Techniques from the field of Artificial Intelligence (AI) will play a significant role in the development of intelligent systems for space operations in the Space Station Freedom era. Innovative approaches to the development of intelligent systems, both robotic and other knowledge based intelligent systems, are desired. Of particular interest are approaches based on the idea that intelligent systems are systems that attempt to achieve goals through the interaction between modifiable subgoals, dynamic descriptions of the environment, and dynamic descriptions of the intelligent system itself. Projects that demonstrate systems which use simply and minimally specified descriptions or models interacting with updating information, e.g. sensor information, in order to perform functions in the following or other Space Station related areas are desirable:

- Intelligent control of robotics for autonomous navigation and for carrying out and other tasks.
- Intelligent systems for process control functions, for automated diagnosis and repair functions, for data monitoring and for status reporting.
- Hierarchical and distributed systems for Space Station subsystem management functions and for Space Station system management functions.
- Also of interest are approaches to knowledge-based systems for engineering design and knowledge capture, tools to aid crew and ground support in updating intelligent system software, innovative approaches to lower level controlling software and hardware in support of intelligent systems, and approaches to increasing the reliability of the Space Station through the application of intelligent systems.

05.06 SUPERVISED AUTONOMOUS SERVICING TECHNOLOGY
Center: JPL

The NASA proposed satellite servicing strategy calls for the establishment of space based, remote/robotic satellite servicing capabilities with ground based supervisory controls. To achieve this goal advances in supervised autonomous technology, using shared and traded control, small scale high precision manipulators, and real time sensory transmission and display are needed.

- Manipulators designed for high precision servicing
  - small, fast, highly position reproducible, modular, high-bandwidth (Hz)/low

volume (megabytes) distributed computing in supervisory control architecture for an integrated robot arm, with automatic active compliance and capable of compensating for time delay from ground controls.

- End effectors with integrated sensory systems
  - arm-hand interface/control coordination in a single processor;
  - end-to-end system capabilities integrating sensors and real-time graphics displays of sensory output;
  - the system should provide multi-mode manual and remote control in position rate, hybrid position rate, hybrid force rate, hybrid position force and direct joint from the same device.

- Ground operator-servicer interface
  - improve cognitive and kinesthetic interactions between operator and servicer systems with special emphasis on performance quantification techniques.

- Vision processing
  - multi-resolution images that retain image information for autonomous machine vision processing and information extracting under lighting conditions that mimic space environment.

- Automatic task planning
  - geometric reasoning, motion planning and knowledge based fault diagnostics and recovery for autonomous servicer systems;
  - control servicer design and architectures.

- Ground and space workstation
  - architectures, displays and input/output controls that provides appropriate cues for mismatches between ground operator response and desired smooth servicer system task performance.

05.07 SPACE MECHANISMS
Center: LeRC

Mechanical automation, robotic manipulation, and mechanized operation will become an increasingly vital part of future space missions. Mechanisms will be required to perform an immense variety of operations. Innovations in all areas of basic mechanism concepts, design, and technology for mechanical motion control, smoothness and necessary reaction compensation are required, including:

- Mechanical technology development will eventually be required for machines for use on Lunar/Martian surface operations, e.g., exploration, excavation, mining. Robustness, fault-tolerance, efficiency, tolerance to environment, and long life are essential qualities.

- Magnetic bearings, cryogenic devices, speed reducers, and other devices to improve performance of future space machinery.

- Bearing design concepts, lubrication techniques, including dry lubrication to improve reliability, reduce torque ripple, and expand performance envelopes.

- Inherently ultraclean (no outgassing, absorption, or particle generation) robots and mechanisms for operation in ultraclean vacuum.

05.08 ROBOTIC ADAPTIVE GRASPING AND MANIPULATION SYSTEMS
Center: JSC

Space robotic systems are envisioned to perform tasks either as assistants to or in lieu of extravehicular activity (EVA) crew members. A dexterous, autonomous system for adaptively grasping and/or manipulating various objects such as tools and spacecraft components is desirable for these systems to minimize the need for unique or task-specific robotic end effectors. A robotic arm, wrist, and hand combined with associated sensor and computer systems is seen as the method for providing the grasping/manipulation capability, striving for human size and performance equivalency as the ultimate goal. Innovations are sought in the following areas:

- Dexterous robotic hand, wrist, and arm design, especially the integration of these elements.

- Sensor systems required to allow object sensing, adaptive grasping, manipulation, and recognition of stable grasps (e.g., force,

tactile, proximity, slip, position, etc.) as well as integration of sensors with a robotic hand, wrist, and arm.

- Computer systems for intelligent, autonomous control of robotic hand, wrist, and arm operation.

- Integrated software systems combining functions associated with grasping/manipulation activities (e.g., object location, grasp region determination, task planning, sensor fusion, grasp/manipulation control, etc.).

- Robotic arms which are capable of grasping and manipulating objects by using the exterior surfaces of the arms, much like large fingers.

- Devices or systems which will allow a human arm, wrist and/or hand to be utilized as a master with bilateral control and sensing features to aid in developing autonomous manipulation capability.

05.09 MISSION SUPPORT FLIGHT ROBOTICS
Center: MSFC

Long duration orbital experiments and missions will require adaptive support by telerobotic systems both onboard and external to the spacecraft. Internal robotics will likely be contained in laboratory-rack sized volumes. Innovative concepts and techniques are needed to conduct telescience effectively. Areas of required innovation include, but are not limited to:

- Advances and improvements in motor drives and control electronics to provide extremely high accuracy and resolution, ultra-low speeds and rates, with very low disturbance and vibration levels in a compact and reliable package.

- Design and develop a dexterous end effector for a small robotic arm that fits within a Space Station experiment rack. The end effector should have the capability to manipulate 3/4"W x 1"L sample chambers, small covers, samples, and horizontal syringes.

- Acquisition and tracking of objects, recognition and 3-D perception of objects in cluttered environment, passive markers and proximity sensing for collision detection and avoidance.

- Robotic control algorithms to control joining two very large payloads together with flexible arms while floating in space with minimum stabilization a disturbance on the system. Guiding the arm's payload from a remote sensor in a different reference frame; control algorithms for distributed architectures including smart joint controllers and remote operator stations.

- Control of remote systems through shared automated/manual methods, remote recovery or path alteration via high level operator control, real-time, realistic interactive graphic simulations of remote task with time delay effects; user friendly intelligent visual inspection system to monitor visual parameters. Efficient integrated real-time operator presentation of multiple sensors including real-time 3-D audio tracking of targets.

- Miniature lighting and guides to illuminate and record very small specimens. It must be non-interfering, proper spectrum, cool and adaptable for micro-g.

- Design and develop anthropomorphic teleoperation input devices and end effectors with force-reflection in the Master-Slave Mode.

06.00 COMPUTER SCIENCES AND APPLICATIONS

06.01 ENGINEERING COMPUTER SCIENCE
Center: LaRC

Application of high-speed computing to large-scale problems, as in the area of computational fluid dynamics (CFD), requires new capabilities for improved computational speed, for input and output data handling, and for presentation of results in understandable ways. The applications of interest are scientific computations requiring rates on the order of billions floating point operations per second on arrays of several million elements. Parallel processing is expected to be used to achieve these speeds. Innovative new concepts and approaches are solicited to meet the following requirements:

- Software to ease the task of developing efficient programs for parallel processing

computers and to retain the efficiency of programs transferred from one architectural design to another.

- Software to exploit the advantages of parallel computing in solving significant real-world problems, as for example in complex-geometry CFD.

- Software and hardware systems to manage, structure and handle enormous scientific/engineering computational data bases.

- Software and hardware systems to facilitate the preparation of input (particularly complex grid systems) and the analysis of results interactively, using graphic engineering workstations networked to supercomputers.

- Graphical concepts (implementable in software or hardware) for visualizing computational results in ways which can bring new understanding to the physical phenomena being modeled, with an emphasis on display of several physical quantities varying over three dimensions and time.

06.02 SOFTWARE DEVELOPMENT AND MAINTENANCE
Center: GSFC

Innovative approaches are needed to support the development, verification, maintenance, and enhancement of large scale, complex software systems. Techniques, tools, and support environments are needed to reduce life cycle costs and improve the process of specifying and meeting application requirements for software development projects involving complex spacecraft control and data handling functions and requiring large development teams. Advanced support systems of particular interest to NASA include management control and tracking, requirements analyses and design specification, analysis and verification methods, development languages and support libraries, reusable software base development and systems integration techniques, code verification and testing techniques, and adapting and maintaining software for long-term missions and projects (10 to 20 years). Special support systems are needed for developing and testing time-critical applications, distributed system software, and fault-tolerant software. All such support systems must provide good documentation and visibility for the users. Potential applications extend across all NASA activities.

Innovations are sought for handling the large amounts of digital data stored during spacecraft testing using advanced technologies to enhance project resources. Improved storage technologies are needed to handle the growing mountains of data associated with increasingly sophisticated satellites. Suggested areas for innovation are:

- Storage of multiple sources of information from a wide range of devices with different data rates.

- Storage of different types of digital information.

- An adaptable system which can assimilate data from multiple points.

- Data space minimization.

- Data that can easily be retrieved.

06.03 RELIABLE SOFTWARE DEVELOPMENT
Center: LaRC

Innovative approaches are sought for the development and verification of very reliable software. These might include computer-aided support of requirements analysis and design specification, executable specification languages, automatic program generators, programming language features to improve software reliability, automated testing and verification techniques, and software safety and risk assessment methods. Of particular concern are programming languages and environments for developing time-critical applications, distributed and parallel software, and fault-tolerant software. Potential applications extend across all NASA activities.

Offerors are cautioned not to propose concepts and approaches already studied extensively in recent years or currently being pursued in many related objectives funded by the Department of Defense.

06.04 KNOWLEDGE-BASED SYSTEMS TECHNOLOGIES FOR AEROSPACE APPLICATIONS
Center: ARC

Knowledge acquisition, representation, and utilization are the key elements for the effective development and implementation of

advanced software systems for spaceborne, airborne, and earth-based applications. At the current time there exists a need for skilled knowledge engineers to translate the expert's knowledge to heuristic rules for the applicable technical domain. Commercial "shells" are available which ease this translation, but they are very domain specific and are not efficient when interacting with unreliable data or with multiple technical domains. Development of knowledge engineering technology is needed in areas such as:

- Knowledge acquisition, representation, and maintenance for large-scale, multi-use knowledge bases.
- Integration of data base and knowledge-base technology.
- Machine learning for automated data analysis and automatic improvement of problem-solving systems.
- Hierarchical control architectures for distributed knowledge-based systems.
- Task planning and reasoning systems capable of operating in dynamic domains with rich representation capabilities to enable reasoning about concurrency and subsystem interaction.
- Man-machine interfaces capable of displaying integrated dynamic system relationships that are understandable and accessible to the human at a higher level of communication; i.e., allows the operator to input into the computer in a flexible and natural manner what is desired and the reason for the request.

06.05 SOFTWARE SYSTEMS FOR MISSION PLANNING AND FLIGHT CONTROL
Center: JSC

Innovative new concepts, such as AI and graphics, are needed to improve the techniques for pre-flight and real-time mission planning and control in support of flight operations of the Space Shuttle and the Space Station. Examples of areas of high interest include:

- Automated knowledge acquisition expert systems.
- Intelligent, computer-aided training systems and computer-aided engineering (CAE) systems.
- Artificial neural systems
- AI applications, such as concurrent AI on parallel processors, real-time distributed database systems for parallel processors, auto decomposition of programs on parallel processors, integration of different AI systems (vision, speech, expert systems, etc.), fuzzy logic, and porting AI software to Ada.
- High fidelity, single frame graphics systems.
- Three-dimensional graphics object generation systems.

06.06 COMPUTER SCIENCES IN COMPUTATIONAL PHYSICS
Center: ARC

Computational physics is a powerful and cost-effective tool for solving a large class of aerospace problems. Innovative computer science concepts are needed to move the state of the art forward and hasten its availability for greater use. Innovative methods are sought for increasing computing speed, mass storage, longhaul communications, and computer graphics. Some examples are:

- Methods for applying parallel processing and for predicting system performance prior to construction. Architectures of interest include multiple instruction-stream multiple data-stream (MIMD), systolic arrays, data flow, demand driven and reduction machines. In addition to hardware architectures and performance prediction techniques, innovation in the supporting systems software (operating systems, programming languages, debuggers, etc.) is sought.
- Computer graphics for visualizing complex, three-dimensional, fluid flow phenomena derived from computation or experiment. Specific techniques include enhanced display of internal flow structures, depth perception, quantitative comparison of numerical and experimental fluid flow data, and high-speed but cost-effective image processing techniques suitable for analysis and synthesis of fluid dynamics data.

- Advanced data storage and data compression techniques.

06.07 LARGE MULTIPROCESSOR DATABASE TECHNOLOGY
Center: JPL

Improved algorithms are needed for distributed-memory multiprocessor machines. These machines have tens to hundreds of processors, each with megabytes of memory, no global memory, and mass storage on one, some, or all processors.

The many processors may be synchronized using an optimistic-execution protocol such as "Time Warp" (generalized rollback), so that the entire machine may be programmed as a unit for large scale, asynchronous applications (e.g., discrete event simulation).

Conventional database algorithms are not designed for use with optimistic execution, and cannot take advantage of it. Innovative techniques and algorithms are needed to facilitate rapid and efficient processor access to arbitrary data located in very large data bases on mass storage associated with these multiprocessors in an optimistic-execution environment. For example, such algorithms might employ optimistic look-ahead or caching techniques with the mass storage devices to complement the optimistic-processor synchronization technique.

Appropriate algorithms are also needed to facilitate the integration of rule-based (AI) code into objects in an optimistic-execution environment on a multiprocessor.

Proposed algorithms should be compatible with object-oriented programming and suitable for implementation in any appropriate programming language, including C++ and Ada. They should work on a range of distributed-memory machines, regardless of details of topology or mass storage, and be portable from one machine or machine generation to another. The algorithms should take full advantage of available hardware while not relying on specialized features not generally found on this class of multiprocessor.

06.08 SPACE FLIGHT DATA SYSTEMS
Center: GSFC

Innovations are required in the following areas of technology for space flight data systems:

- Standard spacecraft distributed software architecture for use in a distributed (non-shared memory) spacecraft computer system. Of particular interest would be elimination of the need to have knowledge of the modules of the underlying computer system and inclusion of a generic definition of the modules in the system in terms of their control and data characteristics.

- Ada flight software methodology for spacecraft software development using Ada programming language. Such an environment would be used for facilitating the cycle of designing, testing, and evaluating flight software. Commercial off-the-shelf software development tools should be identified and innovative recommendations made for other necessary tools. The following are to be addressed:

  - Requirements analysis of system;
  - Preliminary design;
  - Detailed design;
  - Software coding.

- Flight supercomputer for the 1990's for a flight experiment on the Hitchhiker class missions. The problem is the assessment of various computer architectures in the limited flight environment available for testing. Applications include onboard processing of imaging data, data compression, and sensor and control systems management.

- Embeddable data systems components that use state-of-the-art VLSI technology to multiplex telemetry and command signals and that are small and inexpensive such that they can be directly embedded in the payloads and sensors. The problem is the complexity of the interface between spacecraft payloads and the data system which adversely affects reliability, testability, and weight.

06.09 SHUTTLE AND PAYLOAD GROUND PROCESSING SYSTEMS
Center: KSC

Significant reductions in ground processing times for the Space Shuttle vehicle and payloads may be achieved with the application of Artificial Intelligence technologies. Proposals are solicited for innovative improvements in these functions.

- Operational tasks involved in processing the STS vehicle and payload processing/integration are governed by documented step-by-step instructions and signature requirements called Operations and Maintenance Instructions (OMIs). An automated system is needed which can give all personnel the ability to receive, query and provide input to an OMI without requiring paper copies. Automation of the paper-based system must address management, storage, modification, retrieval, user delivery, and usage of the data and the text automated system. To achieve this goal, innovative techniques should address the following areas:

  - Intelligent knowledge-based management for functional knowledge representation;
  - Automated knowledge generation from structured text;
  - High-speed knowledge-based storage and search techniques;
  - Watchdog user delivery techniques which prevent task execution in an incorrect order;
  - Connected networks as applied to interdependent procedural requirements;
  - Knowledge compilation mechanisms for forming use-specific versions of knowledge;
  - Intelligent front-ends which can tailor the delivered data to the specific role of the user;
  - Electronic signature methods.

- Scheduling STS vehicle and payload processing/integration follows a similar, paper intensive process. Currently, scheduling is largely manual, paper-driven \and personnel-intensive. Development of innovative intelligent systems is sought which address the following areas:

  - Constraint-based analysis of planning and scheduling alternatives;
  - Highly interactive, man-machine front-ends which permit distributed interactive scheduling;
  - Intelligent data delivery systems;
  - Interactive work balancing;
  - Historical assignment data base;
  - Task assignment to personnel commensurate with experience, background, etc.
  - Tracking of payload test assignments.
  - Distributed, multi-user architecture.
  - Automated report generation.

06.10 OPTICAL PROCESSING TECHNOLOGY
Center: ARC

Optical processors show promise for pattern recognition and control tasks for space borne applications in which size, weight, power, and speed are critical characteristics. Flight testing and actual use of such systems require the innovative development of two components described below:

- General purpose, optical, vector-matrix multipliers are required for several feedback and control systems. The processor should be able to calculate the product of a 256 element vector with a 256 x 256 element matrix, at 8 bits precision, in a time competitive with a high-speed, digital array processor (100 μsecs). A hybrid opto-electronic design will probably be necessary to reach the desired precision and would be an acceptable compromise. The processor should be easily interfaced to a host computer system. Size, weight, and power requirements should be minimized.

- Optical correlators are needed for pattern recognition and control feedback tasks, but the laboratory bench mounted versions common now are much too large and massive for flight systems. A compact, lightweight, programmable, optical correlator is required. It should have an optically or electronically addressed input image plane and an electronically addressed filter plane, both of which can be updated in real time (100Hz or better). It should be small, light weight, rugged, and with low power requirements. It should be designed with future space qualification in mind.

06.11 ANALYSIS AND SYNTHESIS OF ENGINEERING SYSTEMS
Center: LaRC

Engineering systems are composed of many elements that form subsystems, and their design is governed by a number of distinct

engineering disciplines. These subsystems and disciplines confront the designer with a complex web of requirements, mutual influences, and solutions among which the best alternatives must be found. An innovative design analysis and optimization methodology is required for (1) extension of disciplinary analyses to produce information on the solution sensitivity to the problem variables, (2) efficient optimization methods, (3) best use of modern computer software and hardware technology, such as parallel- processing and expert systems, (4) systematic decomposition, and (5) multilevel optimization of engineering systems. Development of the methodology should include integration of new and existing methods with innovative concepts and verification through test cases. The term "methodology" means a body of techniques, algorithms, and methods unified by a common purpose. Moreover, the deliverables of the development shall take the form of a documented computer code preferably with data demonstrating validity and the usefulness of the methodology.

Although emphasis is on optimization of multidisciplinary systems, the proposed innovations may be specialized and limited to optimization of structures. Opportunities exist for the development of general purpose analytical tools that will extend the methodology into a variety of fields of engineering and systems design.

07.00 INFORMATION SYSTEMS AND DATA HANDLING

07.01 FOCAL-PLANE IMAGE PROCESSING
Center: LaRC

The end-to-end performance of image gathering and processing for high-resolution television and vision-based robotics is severely constrained in many applications by the transformation of visual information from two-dimensional and three-dimensional image-gathering systems into a serial stream of data for subsequent transmission and processing by computers. Innovations in focal-plane image-processing techniques are solicited which would overcome this constraint. These innovations may typically be concerned with coding for image compression, detecting edges and segmenting images, analyzing features in the image for patterns of interest, detecting and tracking moving objects, and restoring or enhancing images. The techniques may typically include integrated sensor-array sensing and processing, multi-resolution parallel processing, Gabor elementary signal coding, correlation and feature extraction, shift-and-distortion-invariant recognition, and optical and acousto-optic processing.

07.02 EARTH OBSERVING SYSTEM DATA TECHNOLOGIES
Center: GSFC

The era of NASA's Earth Observing System (EOS) will generate several problems for dealing with large volumes of data. Areas of innovation include, but are not limited to:

- Compression
  - Development of a high-speed lossless data compression system that could be adapted for use on space platforms;
  - Development of high-speed lossy data compression techniques that measure quality based on the data (usually analysis with computer algorithms) rather than visual impression. Of special interest are techniques for compressing high spatial or spectral resolution image data;
  - Development of analysis techniques that effectively exploit the spectral and spatial information content of high spatial or spectral resolution image data.

- Archiving
  - Software techniques to integrate an optical jukebox subsystem (write once, read many, WORM) into an extant environment in a seamless manner using existing modular tools;
  - Automated data management techniques to transfer and track files and volumes between anaoptical jukebox and other mass storage facilities, such as magnetic disk, magnetic tape and a networked mass storage system;
  - Facilities that can support the smooth flow of data production, storage and retrieval scenarios for a diversity of users, including science analysts, operations staff and demonstrations.

- Visualization Techniques

- Generic data representation and analysis methodologies and software architectures incorporating visualization technologies;
- Interoperable systems, within which a user is able to visually interact with data and information.
- Techniques based on new hardware architectures mapped transparently into software.

07.03 SIMULATION MODEL FOR MULTISPECTRAL SENSORS AND IMAGING SYSTEMS
Center: SSC

The development of multispectral scanners and imaging systems requires the analysis of a large number of parameters for developing the optimal design for particular applications. Currently the information must be gathered from a large number of sources and is not easily compiled to a form which provides an overall assessment of the performance requirements of the scanner or imaging system.

Innovations are sought for a model which would allow the input of the various parameters which describe or affect the sensor design and output probabilities of fulfilling the requirements of the application.

- Integrated image processing algorithms would then incorporate data from the model to compare results of actual system performance verses performance predicted by the model.

- Parameters to be input to the model include but are not limited to spectral bands of interest, blackbody curves, illumination of the target, actual target parameters, atmospheric conditions, performance of optical elements, detector performance and any other data which which affect the design of the sensor.

- The model itself should take the form of a top level system broken down into major subsystems. Each subsystem should output *probablistic* as well as *deterministic* information which would then provide overall system information.

07.04 SPATIAL DATA MANAGEMENT AND GEOGRAPHIC INFORMATION SYSTEMS
Center: SSC

The development of geo-referenced databases for analysis of multivariate data within the environment of a Geographic Information System (GIS) has increased the use of remotely sensed data. Several techniques exist to input data from a wide variety of sources including map, photo, and digital cartographic data. Although these data are input through a wide variety of technologies, the time and effort to build a database is still great and represents a significant problem to the application GIS analysis to a wide range of problems. Furthermore, technical issues including the incorporation of expert systems technology, data structure conversion, and data storage are fundamental areas of investigation which would improve the use of this technology.

Innovations are sought which would significantly reduce the time and effort to input data into a digital database and increase the analytical capability of GIS technology.

07.05 GEOGRAPHIC INFORMATION SYSTEM SOFTWARE DEVELOPMENT
Center: SSC

Current Geographic Information System (GIS) software is in general able internally to handle data in one format, with one method of storage, and at one level of resolution. The best systems have limited capability to use two formats, typically either raster-dominate-vector-subordinate or vector-dominate-raster-subordinate. This is an unnecessary restriction on practical application of the GIS concept. Therefore innovations are sought in the GIS software system which are not data-format constrained, are unrestricted in data storage access, and can process data of mixed resolutions.

One approach might be to specify all operations to be done in terms of an arbitrary reference system which could be based on the geoid. The software would perform internally a specified function by extracting data from the required files based on how or where the data relates to the arbitration reference system. Thus the software could process raster data of mixed resolutions and mix data storage

types. Also, processing of one type of data could readily be controlled by definitions in one or more different types of data. To illustrate, the following question could be posed for the software to answer: "What file contains, at each point on a grid of 3.1416 units of the reference system, the maximum gradient in all thermal imagery data, of resolution less than 15 meters, which is within rectangular limits ($X_1,Y_1;X_2,Y_2$) and within a referenced polygon. Only those files which have associated radiosonde data, where the balloon went more than 20,000 meters, are to be considered. Also disallow data sets which have been noted as having noise in the thermal bands."

The needed software should have effectively no limit on the amount of data which can be read and used in a process. Existing databases, containing just the imagery for a single project of limited scope, already exceed several Gbytes. All of this data must be processed for certain operations.

07.06 INFORMATION PROCESSING TECHNOLOGY AND INTEGRATED DATA SYSTEMS
Center: LaRC

High performance, fault tolerant information data systems are needed for advanced aerospace missions. These data systems must be capable of providing data communication bandwidths and processing services well above what are projected for today's spacecraft and aircraft particularly for data systems that have an integrated form where video, voice, and data are simultaneously distributed and processed. Also, these data systems may carry real-time data, therefore, both delays and variability of delay must be kept to a minimum for correct operation. For the higher level communications and processing functions, the delays and variability are dominated by the distributed operating system. For the lower level communications and processing, the delay and variability are dominated by the physical properties of the hardware implementation. Innovations are sought in both the areas of distributed operating systems and hardware implementation for meeting future data system needs. Suggested areas for innovation are:

- Distributed system concepts and implementations for high performance, real-time response, and fault tolerance.
- Network architecture and topology forms that are performance enhancing and fault tolerance enhancing.
- Electro-optical and optical nodes for network control and high-performance interfaces to the network.
- Optical and electro-optical components/devices (fibers/waveguides, couplers, switches, transmitters, receivers, amplifiers) for optical networks.
- Simulation and modeling tools to evaluate candidate multiprocessing and distributed data systems.
- Components, devices, and systems for high-performance erasable optical disk recorder.

07.07 ADVANCED REMOTE SENSING DATABASE TECHNOLOGY
Center: MSFC

Methods for accessing, retrieving, integrating, and interrelating massive sets of data acquired by numerous earth sensors will be required to support the Geosynchronous Earth Observatory (GEO), which is a component of NASA's Mission to Planet Earth initiative. It is anticipated that remotely sensed data on different space and time scales from space-based, airborne, and ground-based platforms will ultimately be \integrated (for analysis or "truthing") and assimilated (with numerical or conceptual models) to increase our understanding of the Earth System.

This subtopic solicits proposals for innovative methods for accessing, correlating and managing the vast amounts of data anticipated.

- Relational data base structures, user interfaces, and algorithms employing knowledge-based systems and machine intelligence that integrate not only the data sets, but the software that analyzes it.
- Application of neural networks to examine the complex time dependent interrelationships between different data types.
- Automated techniques for quality control and "truthing" of global earth science observations.

07.08 HETEROGENEOUS DISTRIBUTED DATA MANAGEMENT
Center: GSFC

A serious problem for the agency, both in the scientific and administrative realms, is the great diversity of computers, operating systems, communications alternatives, database management systems, and databases. To access data from sources other than their own, users are forced to learn a plethora of different languages and access methods. This frequently inhibits, delays or even prevents efficient use of existing systems and further increases the undesirable proliferation. Accordingly, innovations are needed in developing tools for uniformly accessing heterogeneous distributed data. Possible approaches might include the following or other techniques:

- A software kernel with a universal data representation so that the data model can be layered on top of other aggregate data objects (i.e., databases, images, manuscripts, graphics, audiovisuals, maps, etc.) without creating too much overhead.
- Programming language (C, FORTRAN, LISP, ADA, etc.) based data access that will enable users to read/update heterogeneous distributed data.
- Terminal based data access that will enable users to read/update heterogeneous distributed data.
- High-level, i.e., SQL-like, operators that will enable users to build new data objects from existing data objects.
- A "library-like" interface that will enable users to locate data in a manner similar to the way in which patrons locate books in a library.
- Automated retrieval aides that will interact with a user and help the user locate data to solve specific problems and when the data is located help the user formulate the query or queries.

07.09 SPACECRAFT ON-BOARD INFORMATION EXTRACTION
Center: JPL

As the spectral and spatial resolution of spacecraft sensors increases, so does the volume of data to be stored on-board and communicated to earth. Improved on-board storage capacity is required for telemetry link buffering, with random access memory for real time processing. Space-to-ground telemetry links are usually constrained. On-board data compression technology can significantly reduce the storage required or increase the information return for a given capacity or bandwidth. Furthermore, it can reduce the cost and complexity of ground data operations and enable fast response to short-term transient scientific events. Innovative proposals are sought in the following areas:

- Magnetic solid state memories, including magnetic RAM and vertical Bloch line memories.
- Tape/head lifetime improvements for rotary head recorders.
- Magneto-resistive heads to improve both rate and capacity of longitudinal recorders.
- Compact form factor erasable optical disk systems to support localized data processing and/or telemetry link buffering.
- Ultra-dense memory concepts using multi-dimensional optical storage or atomic level information storage.
- Memory architectures which enhance the performance of memory devices, increase concurrency in input and output stages, improves responsiveness of read/write structures, and use hybrid devices and systems.
- High ratio compression techniques and algorithms for multi-spectral and synthetic aperture radar imaging applications, for stereo imaging from orbit and/or on a planetary surface, and using fractals or neural networks.
- Efficient architectures and implementation of data compression and information extraction techniques for space applications, e.g. for ice and snow extent and for biophysical data.

07.10 COMPUTATIONAL LIBRARIES FOR MASSIVELY PARALLEL COMPUTING SYSTEMS
Center: GSFC

As earth system models become more complex and space and earth science data volumes

become more immense, NASA's need for high rate data processing increases. Much of this processing work load can be readily performed by computers with a very large number of processing elements controlled by a main control unit. This type of computer architecture is generally called the Single-Instruction-stream Multiple-Data-stream (SIMD).

Many NASA applications have been shown to execute rapidly on massively parallel SIMD computing architecture including image processing and analysis, signal processing, and numerical modeling of physical systems. The SIMD architecture is a good match since many of these applications involve massive amounts of data elements, all being processed in a similar manner. The SIMD architecture also has the potential to scale teraflop performance in the 1990s and has a cost/performance ratio significantly better than conventional vector supercomputers.

Large SIMD massively parallel systems are now available commercially. Examples are Thinking Machine's CM-2, Active Memory Technology's DAP, and MasPar's MP-1.

Extensive software libraries are needed for the commercial massively parallel systems in order for users to accomplish productive work in a rapid fashion. Libraries are desired which offer mathematical solution methods including:

- Solving sparse linear systems
- Solving sets of tridiagonal equations
- Application of finite element and semi-implicit methods
- Solution of partial differential equations
- Image segmentation algorithms
- Application of discriminant functions to large volumes of data
- Calculating spatial derivatives
- Computing time integrals
- Performing Fourier transforms
- Computation of statistical functions

07.11 PLANETARY DATA SYSTEM EDUCATIONAL SOFTWARE
Center: JPL

NASA's thirty years of solar system exploration has produced a wealth of information about the earth and other planets. This program is intended to apply the accomplishments of the planetary program to education by utilizing computer technology which uniquely offers the required data capacity, staging flexibility, and widespread availability. The goal of this task is to develop effective fully interactive educational software based on the themes, accomplishments, and scientific results of the NASA planetary exploration program. Innovative software is required that:

- Utilizes interactive CD-ROM technology suitable for use with school computers including the IBM PC (EGA and VGA graphics), Apple II GS and Apple Macintosh.
- Utilizes software structures that maximize the attractiveness, flexibility and friendliness and interactive nature of the product. The program should use graphical displays, audio and animations to present the material, and require frequent interactive choices by the users.
- Emphasizes challenge, problem-solving, and special approaches to increase the potential educational effect.
- Provides an implementation easily adaptble to the handicapped, to minorities and a range of student levels.
- Should be easily developed into a viable commercial product with applications beyond NASA needs.

08.00 INSTRUMENTATION AND SENSORS

08.01 EARTH ATMOSPHERIC SENSING AND TOPOGRAPHIC MEASUREMENTS FROM SPACE
Center: GSFC

Satellite and supporting insitu observations of precipitation rates, cloud cover parameters, and broadband radiation parameters at the surface and top of the atmosphere are needed to satisfy global-scale climate monitoring requirements. This subtopic solicits proposals in the following areas for innovative methods and techniques to help achieve those objectives:

- Active (radar) and passive microwave technology for measuring precipitation.
- I\mproved direct and indirect techniques for measuring rainfall at the surface.
- Improved techniques for interpreting and assimilating rainfall data from weather radar and conventional observations. Includes innovative remote sensing algorithms and statistical techniques for applications to "ground-truth" measurements needed to validate satellite estimates of rainfall.
- Methods for global monitoring of broadband, surface-radiation-budget parameters, using satellite and ground-based observations.
- Small, stable light sources for on-board optical tests to establish wavelength and radiometric responses after remote sensing instruments have been placed in orbit.

Laser altimeters being developed for high resolution topographic measurements of the Earth's surface from spacecraft platforms need improvements in electrical efficiency, sensor lifetime, ruggedness, and size reduction. Innovations to achieve these objectives are solicited in the following areas:

- Diode-pumped, Q-switched, solid state laser transmitters with a minimum of 100 milliJoule pulse energy at 10 percent or greater electrical-to-optical efficiency.
- Integration of pulse-discriminators, gating electronics, and time-interval counters using hybrid CMOS or GaAs circuitry for miniature size and low-power operation.
- Fabrication of 0.5-meter-diameter or larger ultra-lightweight telescopes for altimetry receivers.
- High repetition-rate (kHz), diode-pumped, solid state laser transmitters capable of Q-switched operation at more than 1 milli-Joule per pulse.

08.02 LOW-COST, HIGH RESOLUTION, AIRBORNE, REMOTE SENSING INSTRUMENTATION FOR EARTH SCIENCES
Center: SSC

Innovations are sought in sensor systems which produce high resolution, low-cost, multi-spectral sensor data for Earth sciences. Spatial resolutions of 10 m, 5 m, 1 m and better are desired for small area analysis. Instruments should have the capability to be mounted in a light aircraft or balloon with the ability for users to display and evaluate the data in real time. Multi-spectral bands between 0.4 μm to 14.0 μm are needed to address NASA's interdisciplinary research activities in such areas as forestry, agriculture, geology, urban geography, geo-botany, and archaeology. Innovations demonstrating commercial use potential, real-time capability, and adaptability to aircraft are or particular interest.

08.03 SENSORS FOR AEROSOL AND CLOUD STUDIES
Center: LaRC

Innovations are solicited in sensor techniques, sensors, and sensor systems for ground-based, airborne, and spaceborne monitoring of atmospheric clouds and aerosols produced naturally or from man's activities, including determination of:

- Vertical concentration profiles.
- Size distribution from submicron to micron particles.
- Particle composition and morphology.
- Aerosol optical properties.
- Aerosol spatial distribution and fluxes.

- Ancillary atmospheric data required for analysis of aerosol properties.

Desired attributes of new concepts might include reduced weight and power, greater reliability, greater resolution, and other significant figures of merit not currently achievable.

08.04 LASER POLARIZATION PROFILING
Center: GSFC

This subtopic solicits proposals for an innovative, compact, low-power laser polarimeter package. Base requirements are a polarized, pulsed laser transmitter, three detectors (two channels with crossed polarizing filters and one wide open channel), and a compact color video camera that allows the laser spot to be clearly seen and the illuminated surface identified. The package will be used at a nominal 300-meters altitude mounted on an operator-pointed, platform-boom extending from a hovering helicopter at dawn or twilight. Data acquisition runs are less than two hours and the video tape must be correlatable with the stored computer data. The camera must be capable of remote controlled zooming for operator monitoring of the surface area of interest. Required performance characteristics are:

- Laser energy appropriate to allow 2 percent variations in polarization to be measured.

- Data acquisition at least one sample every 2-3 seconds.

- The laser spot size variable from at least 0.2 to 2.0 meters at the nominal altitude.

- User friendly and relatively portable allowing convenient ground use for calibration and horizontal measurements.

08.05 EARTH ATMOSPHERIC LIDAR REMOTE SENSING
Center: GSFC

Accurate measurement of the atmospheric temperature, humidity, pressure, and wind fields from aircraft and spacecraft platforms requires high resolution, pulsed, tunable, lasers; light-weight, large-aperture optical components; and infrared detectors. Innovations are needed in the following:

- A single, longitudinal-mode, pulsed laser tunable over the 720 to 770 nm spectral region having frequency setting and long-term frequency stability to better than 0.0005 cm^{-1}; energy-per-pulse greater than 0.15 Joules at 10 Hz; an efficiency above 1 percent; and Q-switched, short-pulse operation of a nominal 100 ns duration.

- Short wavelength diode lasers for pumping alexandrite lasers and single-mode lasers at 720-740 nm for injection seeding.

- Precise frequency measurement and tuning of pulsed lasers at an accuracy 0.001 cm^{-1} including measurement of the spectral energy distribution of pulsed multi-spatial mode lasers.

- High resolution, tunable Fabry-Perot etalons having very high stability and large throughput. Required are a resolution of 0.005 cm^{-1} (etalon fringe FWHM); stability above 1 part in 10^9 short-term and greater than 5 parts in 10^7 long term; a plane, parallel Fabry-Perot etalon aperture greater than 12.5 cm. (Spherical Fabry-Perot etalons should also be considered.)

- Single longitudinal mode pulsed solid state laser operating beyond 1.6 μmwith a bandwidth and stability of $\leq$10-20 MHz.

- High sensitivity, shot-noise-limited detectors for wavelengths above 1.6 μm with a frequency response above 10 MHz.

- Large-aperture, holographic optic elements for scanning telescopes with high diffraction efficiency and single narrow-band and multi-wavelength response especially for 532, 732, 760, 770, 1064, and 10600 nm. Low-weight, cost, and simplified scanning mechanisms are important considerations.

- Ultra-lightweight telescopes using novel approaches such as metal foam materials.

08.06 TUNABLE SOLID-STATE LASERS, DETECTORS, AND LIDAR SUBSYSTEMS
Center: LaRC

Measurements to improve understanding of atmospheric chemistry and dynamics from a polar orbiting platform require development of new solid-state laser and nonlinear optical materials, laser transmitters, detectors, and LIDAR subsystems to meet requirements of energy-per-pulse, efficiency, lifetime, and reliability. Tunable solid-state laser tech-

nology, covering the radiation spectrum from near UV through the IR, is required to conduct scientific experiments to measure atmospheric aerosols, molecular species, and meteorological parameters. More specifically, innovations are sought in the following areas:

- Novel tunable, solid-state laser materials or solid-state laser materials compatible with laser diode pumping. Lasing between 0.7 and 1.1 μm and 1.5 to 2.1 μm are of particular interest.

- Laser diode arrays to optically pump solid-state materials in the 0.76 to 0.81μm or the 1.5 to 2.1 μm spectral ranges.

- Non-linear optical materials to double or triple frequency efficiently at infrared wavelengths, 0.7 to 1.1 μm, or to produce efficient optical parameter oscillators in the mid-IR, 2.5 - 5.5 μm, spectral region.

- High-temperature, superconductor-insulator-superconductor (SIS) detectors in the 100 μm wavelength region.

- Lightweight metal or glass mirrors to serve as collectors of radiant energy for LIDAR applications. Nominal size is on the order of 1.0 meter.

- High speed and/or high quantum efficiency detectors with low noise properties and operating in the 0.9 to 5.5 μm region. Room temperature operation is preferred.

- Hybrid or monolithic detector/preamplifier structures to reduce electronic noise.

- Technology for narrow-band spectral filters having a high spectral resolution, about 10^5, and a high-peak transmission.

08.07 EARTH OBSERVING SENSOR DEVELOPMENT FOR GEOSTATIONARY ORBIT
Center: MSFC

Innovations are desired for the development of a new generation of instrumentation for earth observation to be flown on the geostationary platform. The multi-sensor, multidisciplinary specifications of the platform will require significant improvements in spatial and spectral resolution relative to instruments that are presently flown on operational geostationary satellites. To meet the overall goals of NASA's earth observing, geostationary platform program, innovations are required in:

- Passive microwave systems, specifically, large-aperture antenna systems, low-noise, high frequency amplifiers, and multiple-feed horn design, for atmospheric sounding, sea surface and precipitation measurements.

- High resolution, visible and infrared imaging devices including advanced, high-performance, focal-plane arrays with on-board calibration.

- Data compression, calibration, and on-board signal processing for infrared imaging spectrometers.

- Motion compensation and background suppression techniques to meet pointing accuracy and stability requirements.

08.08 A COLD CORONAGRAPH FOR PLANETARY OBSERVATIONS
Center: JPL

The NASA Planetary Science Program carries out ground-based observations of solar-system objects in the thermal-infrared region of the electromagnetic spectrum. There is a need within that program for an optical system that is capable of reconstructing an image, using apodizing masks, of electromagnetic radiation focused by a telescope in the 5-30 micron wavelength region. The optics and mounting assembly must be able to operate at 77 K so as to minimize thermal noise from the optics in the system. An additional constraint is that the system should accept an f/35 input beam and be capable of excellent quality imaging for fields of view of 15 arc-minutes with pixels that are 100 microns square. A final consideration is that the vacuum dewar, in which the optics are mounted, must have a light path that passes only through vacuum between the detector system and the apodized optics.

08.09 DETECTORS AND DETECTOR ARRAYS
Center: GSFC
Center: JPL

Detectors and detector arrays for space astronomy, astrophysics, geophysics, and atmospheric studies at varying wavelengths require innovations in the following areas:

- Composite cryogenic or room temperature IR bolometers using diamond films, coated with metal for absorbing incident radiation, and attached semiconductor or superconductor thermometers.

- Cryogenically cooled junction field effect transistors (JFETs) (2-4 K) with low noise at low audio frequencies (10 Hz) and low power dissipation.

- Miniature adiabatic demagnetization refrigerators suitable for space flight and capable of achieving 0.1 K.

- Cryogenic low-noise multiplexers for reducing requirements into dewars at 2 K for detectors and for engineering sensors.

- Cryogenic low noise, low power amplifiers with voltage gain at 2 K for helping readout detectors.

- Electronic parts (field effect transistors (FETs), op amps, resistors, capacitors, inductors, sockets, cables, boards) suitable for operation at 2 K to support cryogenic detectors.

- Three-dimensional (energy, x, y) detector arrays for the UV and visible; array detectors for UV cameras, visible blind, high dynamic range.

- Microchannel plate electron intensified arrays with no ion feedback, high quantum efficiency, high resolution, low radioactivity, controlled conductivity, high speed.

- High quantum efficiency near infrared and UV photocathodes.

- Charge-coupled device (CCD) and arrays:
  - improvements or alternatives to traditional overlapping gate structures utilizing submicron fabrication techniques;
  - reduced readout noise (<5 els rms) through the development of lower noise on-chip amplifiers;
  - fabrication on monolithic non-silicon materials;
  - dark current reduction techniques or structures;
  - radiation hardening;
  - non-destructive readout;
  - array size;
  - UV sensitivity;
  - defect reduction;
  - anti-reflection coatings.

- A spaceborne sensor for the direct measurement of magnetospheric currents in space.

- Micro-antennas for efficient coupling to submillimeter, heterodyne-receiver, mixer diodes.

- Compact, unitized temperature sensors with extremely high dR/dT or dV/dT characteristics for temperature monitoring.

- GaAs multiple, quantum-well detectors in the 2-17 μm region.

- Array detectors for UV cameras, visible-blind, high dynamic range.

08.10 LASER HETERODYNE TECHNOLOGY
Center: GSFC

Heterodyne laser systems are important for space astronomy and astrophysical studies. Innovations are required in the following areas:

- Submillimeter laser systems employing a CO_2 pump laser to produce increased tunability with improvements in increased power, reduction in size, and weight.

- Hybrid, output couplers for the 100 to 200 μm region employing meshes and grids for partial FIR reflection and a dielectric substrate for total 10 μm reflection.

- GaAs Schottky mixers in a quasi-optional, corner-cube geometry are used as the mixing element to improve the coupling of the signal with the mixer in a more robust and good beam pattern. Planar mixer designs are suggested with spiral antennas or log periodic structures. Mixer arrays are needed at the. focal plane to improve observing efficiency. Cryogenic operation must also be considered for improved mixing efficiency.

- Photoconductor heterodyne mixers for the 100-200 μm region having large bandwidths or a scanning local oscillator in order to obtain the 500 MHz or greater spectral coverage needed for astronomical sources.

- Semiconductor, diode-laser, local oscillators for heterodyne detection capable of operation at wavelengths longer than 1.5 μm and emitting single-mode, noise-free radiation with output powers approaching 1 mW and an operating temperature above 20 K. Since input power requirements must be minimum and the emitted frequency stabilized (to less than 0.1 MHz), laser threshhold current and temperature-tuning rates must be minimized. The laser local oscillators must be durable and have multi-year operating lifetimes.

08.11 INFRARED TECHNOLOGY FOR ASTRONOMICAL APPLICATIONS
Center: ARC
Center: JPL

Innovative concepts and techniques are needed to support spaceborne infrared astronomical telescope projects:

- Means to achieve ultimate performance in low-background instruments:
  - Improved sensitivity of discrete IR detectors and integrated IR-detector-array electronics operating at cryogenic temperatures;
  - Means to reduce device noise, dark current, and susceptibility to particle radiation; and to provide high uniformity and high radiometric accuracy;
  - Detector arrays and concepts for detector materials with cutoff wavelengths between 2.5 and 300 μm;
  - Advanced multiplexer architecture, interconnect technology, and monolithic structures.

- Area-array focal planes operating with cut-off wavelengths longer than 14 microns and temperatures between 40 K and 80 K and bolometric arrays operating at He^3 temperature.

- Methods to count individual IR photon events, either directly or via up conversion.

- Novel techniques in long-wavelength (>20 microns) IR filter design and manufacture.

- High-quality, low-cost fabrication techniques for optics capable of diffraction-limited performance down to 1 microns. Included are both small optics for instrument applications, and large (>1 m) lightweight panels for use in segmented mirrors.

- Novel techniques are needed for in situ evaluation of image quality in cooled IR telescopes. This includes development of sensing instrumentation and algorithms for correction of focus.

08.12 INFRARED SPECTROSCOPY WITH DETECTOR ARRAYS
Center: MSFC

Astronomical studies of planets, stars, and galaxies require versatile infrared spectrometers combining high wavelength resolution, variable spatial resolution, and high sensitivity. Innovative concepts are needed for spectrometers incorporating the latest infrared array technology and designed for the new generation of large telescopes. The instrument should operate in the 1-5 micron spectral region; have resolving powers in the 500-4000 range with 0.5-3.0 arcsecond spatial resolution; be suitable for use at a 6.5-meter, f/5.5 telescope; include cryogenic cooling for maximum sensitivity throughout the 1-5 micron spectral band; and be computer controlled.

08.13 HIGH-OPERATING-TEMPERATURE INFRARED DETECTOR ARRAYS
Center: JPL

New materials and concepts are required for application of non-cyrogenic infrared detector arrays suitable for operation in the 1.0 to 16.0 μm wavelength regions. Non-cryogenic detector arrays would require concurrent technology development of appropriate multiplexing and interconnect architecture and material having low-noise and dark-current values, high uniformity, and high quantum efficiency at the wavelengths specified.

08.14 SUBMILLIMETER ANTENNAS, RADIOMETERS AND SPECTROMETERS
Center: JPL

Submillimeter antennas and radiometers operating in the 0.1 and 1.0 mm wavelength range for space astronomy, astrophysics and atmospheric studies require innovations in the following areas:

- Antenna systems with apertures up to 4 meters; multiple beams with scan angles of many beamwidths.

- Cryogenic, low-noise, submillimeter radiometers with operating times of two to five years.

- Solid-state, low-power, phase-locked, submillimeter local oscillators up to 3000 GHz with output power greater than 100 microWatts. These local oscillators should have dc power requirements less than 5-10 Watts, be small and light-weight, and have lifetimes of two to five years.

- Multichannel spectrometers to simultaneously analyze IF signal bandwidths up to 10 GHz with frequency resolutions of 1 MHz, small size, lightweight, and low dc power (<10 mW per channel) along with high stability and lifetimes greater than five years.

08.15 HIGH-FIELD VECTOR HELIUM MAGNETOMETER FOR SPACE APPLICATIONS
Center: JPL

The JPL Vector Helium Magnetometer (VHM) has been successfully flown on a number of space missions. It provides optimal performance for magnetic fields less than 500 nT, approximately, with sensitivity decreasing for higher values. However, the instrument can be operated in the scalar mode with relatively minor changes and thereby provide accuracy of about one part per 10^5, at field strengths up to 10^5 nT. New techniques are sought which would enable the instrument to be utilized at fields up to at least 10^5 nT with the accuracy of the scalar-mode operation while simultaneously measuring the direction of the field. The instrument must have low mass and power consumption and be applicable for space flight.

08.16 INSTRUMENT TECHNOLOGY FOR EXOBIOLOGY
Center: ARC

Exobiology requires a large and specialized cadre of analytical instruments and systems for flight experiments in low earth orbit and on planetary missions. These instruments and systems must be highly accurate and precise while performing meaningful analyses on very small samples containing biologically important elements and their molecules. Those instruments are further required to be highly miniaturized and extremely efficient in their use of spacecraft resources requiring innovative concepts and approaches. Examples include the following:

- Miniaturized gas chromatographs and subsystems including innovative detectors, columns, sampling devices, and sample treatment devices (e.g., pyrolyzers and thermal analyzers) to detect and quantify rapidly volatile and organic compounds at parts-per-billion levels.

- Miniaturized, highly rugged devices to measure electrochemical properties (e.g., eH, pH) of extraterrestrial soils.

- Infrared diode lasers and systems capable of operating at elevated temperatures, (>77 K) for molecular spectrometry of gases in the range of 2-5 microns to measure biogenic molecules, e.g., C and N isotopes in CO_2 and NO_X with precision of 0.1 percent or better.

- Miniaturized elemental analysis techniques (e.g., gamma ray and alpha backscatter spectrometers) with extended range and greater sensitivity for the biogenic elements (C, H, N, O, P, and S).

- Systems and subsystems for the production, manipulation, collection, levitation, observation, and analysis of 0.1-100 micron size particles inside an environmentally controlled chamber in a microgravity environment.

08.17 INSTRUMENTATION FOR GEOLOGY
Center: JPL

Commercially available reflectance spectrometers for laboratory use enable measurement of either diffuse or specular infrared reflectance of samples. An innovative device which is capable of providing for multiple angles of measurement is sought for determining the directional reflectance field and its variation with roughness and composition for various polarization angles. Such an instrument would:

- Cover the 2.5 to 22 μm range with less than 4 cm^{-1} resolution and with adjustable angle of polarization;

- Accommodate an adjustable angle of incidence in zenith and azimuth and adjustable angle of reflection in zenith over the range 10 degrees to 80 - 90 degrees;

- Be designed with incident and reflected beam cone angles less than 5 degrees and with an analysis spot diameter which is adjustable from 1 mm to 2 cm, approximately.

Field-portable instrumentation is needed for in situ measurements in support of geologic observations from airborne and satellite instruments. A directional emission spectrometer is required for measurement of the ambient thermal emission of geologic materials. The instrument would:

- Cover the 3-5 μm and 7.5-13.5 μm spectral ranges with less than 4 cm^{-1} resolution, with 500:1 signal-to-noise ratio and an adjustable angle of polarization;

- Allow rapid measurement of a target area 1 to 15 cm in diameter on the ground at any angle between 0 degrees (straight down) and 85 degrees;

- Be capable of averaging spectra and storing at least 100 of these; provide for hard-copy or screen display.

08.18 OCEANOGRAPHIC INSTRUMENTATION
Center: GSFC
Center: JPL

The NASA Oceanic Processes Program and the Interdisciplinary Science Program that will address the fate of atmospheric carbon dioxide in the oceans will use color scanner instrumentation such as the CZCS (Coastal Zone Color Sensor) instrument that has flown on Nimbus-7 and the proposed SeaWifs instrument. While these instruments provide regional and global measures of near-surface biomass in the ocean, the extension of these measures to the distribution of primary productivity requires in situ measurements to support calibration, atmospheric-correction and in-water algorithm development, and validation of derived products for algorithm development and verification. The instrumentation will be used both for sampling at discrete stations from oceanographic vessels and for gathering time series data on primary productivity from moorings at selected sites. These data will be used in support of the international Joint Global Ocean Flux Study (JGOFS).

Specifically, innovations in the following areas are solicited:

- Turn-key aircraft instrument systems for measurements of ocean reflectance and brightness temperatures at space sensor wavelengths and for laser-stimulated fluorescence and depth profiles of optical scattering. Flight on private aircraft, calibration, navigation, and on-board analysis should be considered.

- Expendable optical drifting buoys to measure, at the surface, upwelled radiance and downwelled irradiance at satellite visible-to-near-IR sensor bands to provide accurate estimates of water-leaving radiance for comparison with satellite data. Aircraft deployment, greater-than-4-month lifetime, calibration, anti-foulant approaches, and satellite data collection should be considered.

- Instruments for use on moored and drifting buoys and on board ships for estimation of near surface or depth profiles of apparent, inherent, or laser-induced optical properties in narrow bands from 400 nm to 900 nm necessary for derivation of bio-optical state; shipboard sensors for surface brightness temperature at 5 bands in the 3-4 and 10-11 micron regions with 0.02 K precision.

- In situ optical instruments for use on moored or drifting buoys and on board ships for rapid evaluation of the surface and vertical profiles (to depths of 200 meters) of primary productivity of marine phytoplankton based on chlorophyll fluorescence either from solar or contained sources. Lifetime, power, precision of calibration, satellite location and data relay are important in buoy systems.

08.19 OPTICAL COMPONENTS AND DESIGN TOOLS
Center: GSFC
Center: JPL

Optical design tools, materials, coatings, and devices are needed to support optical instrument development for earth science, planetary science and astrophysics. Innovations are needed for the following:

- Novel approaches and analyses for design, tolerance measurement, and optical performance evaluation of space flight optics including the analysis and optimization of the optical design of IR and submillimeter systems, and the precise

modeling of blaze efficiency of diffraction grating spectrographs.

- Wide-field x-ray telescopes for the 0.1 to 8 keV region offering high angular resolution over a wide field of view.

- Optical image reconstruction from partial u-v plane coverage.

- Thin films, metrology systems, amplitude and phase masks, and models for white-light, all-reflecting coronagraphs having an 80-400 cm aperture and the abililty to control narrow-angle (sub arc-minute) scattered light in imaging systems to one part in 10^{10}.

- Diffraction gratings with high efficiency, low scatter, and reduced optical aberrations.

- High-throughput, adaptive-imaging spectrometers that could be space qualified for use in the 300 to 1,000 nanometer range at spectral resolutions of 100 to 10,000.

- High-reliability, long-lifetime optical coatings in the 9 to 11 micron range for beam splitter applications with pulsed TEA-CO2 laser systems. Optical coatings for use in the extreme ultraviolet to far IR spectral region. Low scatter coatings for conventional and grazing incidence mirrors for the spectral region above 5 nanometers.

- Low-scatter, high-temperature superconductor materials on optical surfaces.

- Concepts and designs for coating and cleaning mirrors and other critical optical surfaces in space.

- A vacuum-compatible optical monitoring system to monitor and control layer thicknesses of the order of 10 nanometers for use in producing multilayer coatings for the EUV and soft x-ray spectral regions.

- Techniques for controlling contaminants on fragile, critical surfaces such as thin-foil x-ray filters operated at cryogenic temperatures.

- Low-z, high x-ray-transmittance meshes for x-ray filters.

- Apparatus for the measurement of the refractive index of materials as a function of temperature from 4 K to 273 K.

- Compact, three-dimensional cameras for human and machine vision that would be light-weight, high resolution single lens active systems with real time capability for navigation.

08.20 OPTICAL FABRICATION AND METROLOGY
Center: MSFC

Innovations are desired in the areas of optical fabrication and metrology. In order to produce large optical systems for space-based operation, improvements are required to develop a more deterministic approach to fabrication. This requires developments in the grinding and polish process and in the accompanying metrology. Areas of interest include:

- High speed direct surface generation.

- Force adaptive grinding.

- Nondestructive subsurface damage evaluation.

- Long path figure and surface roughness measurement.

08.21 SPACECRAFT CONTAMINATION MONITORING
Center: GSFC

Environmental monitoring is needed to verify the performance of spacecraft systems during orbital operations. The performance of attached payloads on the Space Station, for instance, will be optimal only if, at any given time, the experimenters have a clear understanding of the operational environment and its effects on the payload. Monitoring systems must measure reliably the concentration of the contaminant species surrounding the spacecraft and affecting parameters such as column density, surface deposition, spectral background, etc.

The development and the verification of on-orbit mass transfer models depend on the in situ measurement of the relevant environmental parameters, such as the relative concentration of natural species, and the amount, velocity and direction of molecules in

the induced environment. Innovative instrumentation to perform these tasks is needed. Particularly desirable are fast, highly sensitive detectors for real time identification of undesired species. Ideally, the range of detectable molecular weight extends from 2-4 amu to about 150-200 amu.

08.22 HIGH RESOLUTION CHARGED PARTICLE INSTRUMENTATION
Center: GSFC

High precision elemental and isotopic abundance measurements over a wide variety of energies are required to interpret different models of energetic particle production and propagation. Balloon-borne magnetic spectrometers offer great potential in making these kinds of measurements on galactic cosmic rays. Innovations are desired in the following areas:

- Cherenkov Detector Developments:
  - Ring-imaging, proximity-focused Cherenkov counters for measuring velocity by measuring the angle of Cherenkov emission. Ultraviolet sensitive detectors are optimal;
  - New, low-density solids with index of refraction, n between 1.02 and 1.3. The material properties such as absorption and scattering lengths, optical dispersion, and mechanical stability are important.
- Magnetic Field Instrumentation:
  - Submillimeter-sized probes (e.g., MRI or Hull probes) for magnetic field monitoring on special scales of 20 microns in high intensity (.01 to 3 Tesla) and high gradient (0.2 T/cm) fields.
- Trajectory Detector Systems with a spatial resolution on the order of 10-30 microns:
  - Thin films and/or powders of electron trapping semiconductors sensitive 1.06 microns or 1.30 microns. These materials must be on equally thin substrates (quarter mill) to minimize multiple coulomb scattering;
  - Half-meter-sized arrays of this material;
  - A laser system (e.g., semiconductor array containing multiple lasers mated to micron sized optical fibers) and/or mechanical scanning system for fast, high precision readout.

08.23 DETECTORS FOR GAMMA RAY ASTRONOMY
Center: GSFC

Detectors for gamma ray astronomy require innovations in the following areas:

- Low-noise, low-temperature (approximately 100 K) junction field effect transistors (JFETs) for use with solid state detectors for x-ray and gamma ray spectroscopy.
- Segmented germanium detectors for position sensitivity and background rejection.
- Large-volume (greater than 300 cm^3), high-purity, n-type germanium detectors.
- Large-volume, high-density, high-atomic-number scintillators for shielding of gamma ray spectrometers. Examples are bismuth and lead carbonate.
- Low-noise photodiodes for use with scintillation detectors.
- Large-volume (greater than 1 cm^3) ballistic phonon detectors for ultra-high energy resolution (<100 eV at 1 MeV) for gamma ray spectroscopy.
- Low-noise, low-temperature GaAs FET amplifiers.
- High-sensitivity, magnetic SQUIDs for photon and particle detectors.
- High-pressure (2 to 40 atmospheres), low-mass vessels for gaseous photon and particle detector.
- High-temperature, CdTe solid state detectors for imaging and spectroscopy.
- Improved performance plastic scintillating fibers for detecting gamma rays and particles.

08.24 GAMMA RAY AND X-RAY SPECTROSCOPY
Center: JPL

New concepts and techniques are needed for gamma ray and x-ray spectroscopy. Future space missions will require x-ray and gamma ray spectroscopy in orbit as well as on planetary, lunar and other solar system bodies. Miniature, low power analytic instruments with

gamma ray and x-ray spectroscopy capability are needed to perform in situ science and to support sample selection for return to earth. New detector concepts are needed to fit mission limits on size, mass and power while providing good spectral resolution and high efficiency through large volumes (at least several cm^3) and/or large areas (at least cm^2).

Existing high-efficiency gamma ray detectors require cooling to cryogenic temperatures, have severe sacrifices in spectral quality, and may require cumbersome photomultiplier-scintillator combinations with reduced spectral resolution. Existing detectors for x-rays require cryogenic cooling, and cumbersome arraying is needed to achieve large areas with good spectral resolution. Candidate innovations might include new compounds for direct-ionization detection of gamma rays and x-rays, new "scintillator"-photodetector combinations, or innovative electronic methods for improving the spectral resolution of existing systems. The materials of the detector systems should be able to withstand the temperature extremes and the thousands of Gs accelerations associated with many space missions. Systems with the added potential for imaging in square centimeter areas without extensive amplifier arrays or CCD-like digital readouts would be particularly interesting.

08.25 UNDERWATER POSITION THREE-DIMENSIONAL MEASURING SYSTEM
Center: MSFC

Innovations in an underwater position location system are sought to supplement the qualitative video data presently gathered at the Neutral Buoyancy Simulator (NBS) with quantitative measurements. Past experience indicates that accurate three-dimensional measurements are required during the hardware development and testing phase at the NBS. The sensor should be capable of detecting specified targets at distances up to 75 feet with a resolution of 0.063 inch. These sensors will be used as part of an underwater measuring system in a steel tank 75 feet in diameter and 40 feet deep. Therefore, reflection must be considered and limited without modifications to the tank walls. A three-dimensional coordinate position point corresponding to the target position is desired after processing the data from the sensors. These position points will be used to drive computer controlled equipment.

08.26 NONINVASIVE FLUID MEASURING INSTRUMENT
Center: KSC

The requirement exists for a portable, noninvasive, hand-held fluid measurements instrument (similar to a Volt-Ohm meter) which allows digital readout of gaseous flow rate, pressure, and temperature on various gases, primarily GN_2 and Helium. The unit should be capable of selecting gas type, range desired, register pressures up to 100 psig and be used open or closed loop. Consideration will also be given to innovations meeting the above objectives which require minimal invasion/disassembly of assembled fluid systems.

09.00 SPACECRAFT SYSTEMS AND SUBSYSTEMS

09.01 CONTROL OF LARGE SPACE STRUCTURES
Center: LaRC

Future space missions are expected to require large spacecraft which are loosely coupled and highly flexible. These spacecraft will require, innovative design concepts for control systems and components which are more reliable and more efficient than current systems. The objectives of these innovations must embody:

- Advanced control system analysis and synthesis techniques.
- Fault identification, isolation and reconfiguration.
- Methodology to integrate control and structure systems and associated components.
- Adaptive control strategies for systems with appreciable structural dynamics.

The focus should be on both control systems design and control devices and may involve ground validation of advanced system concepts and attendant breadboard hardware in Phase II or subsequent R&D activities.

09.02 GUIDANCE, NAVIGATION AND CONTROL OF ADVANCED SPACE TRANSPORTATION SYSTEMS
Center: LaRC

Future space transportation systems include heavy lift launch vehicles (HLLVs), aerobraking orbital transfer vehicles (AOTVs), Shuttle II, Shuttle C, transatmospheric vehicles, and interplanetary spacecraft. To permit the economic viability of such systems, advanced techniques for guidance, navigation, and control (GN&C) must be developed to improve system reliability, autonomy, and operational capability and to reduce life-cycle costs. Innovations not based on conventional design or existing systems are solicited to improve existing practices:

- Autonomous GN&C techniques which can be implemented on a typical flight computer.
- GN&C methods which can readily adapt to environmental uncertainties encountered by an AOTV or an HLLV during maneuvers in the atmosphere.

09.03 DIGITAL PROCESSOR FOR AN EARTH HORIZON SCANNER ATTITUDE CONTROL SYSTEM
Center: GSFC

Innovations are sought for a simple, low-cost digital processor that will accept signals from various attitude sensors and produce control signals for various torquers in a low-earth-orbit spacecraft. The sensors will include but not be limited to earth horizon scanners, magnetometers, and rate gyros. The torquers include reaction wheels, magnets, and cold gas jets. The processor shall be capable of simultaneously handling sensors and torquers with bandwidths of up to several cycles per second and shall be easily and quickly reprogrammed. It must be able to handle spacecraft telemetry and command-control functions without significant degradation of the control functions. Low weight and power, as well as low cost, are also essential to permit the processor to be used on small spacecraft.

09.04 SPACECRAFT FLIGHT DYNAMICS
Center: GSFC

The Flight Dynamics Facility at GSFC is involved in ground-based determination of spacecraft attitude, in-flight calibration and alignment of attitude sensors, and the development and operation of simulators for spacecraft attitude dynamics and control. Future emphasis will be on performing these functions using generalized and efficient algorithms operating in a near real time environment. Increased use of PC workstations rather than mainframes for operational computations is also expected. Innovations are sought for new attitude determination approaches, algorithms and procedures for sensor calibration and alignment, and modeling techniques for evaluating spacecraft dynamic behavior. Specifically, proposals are desired which address the following:

- Techniques which efficiently identify corrupted or erroneous sensor measurements during attitude determination on the ground.
- Generalization of attitude determination techniques and filters which might be implemented in multi-mission support software.
- Gyroless dynamic modeling as it relates to enhancing spacecraft attitude control with limited sensor observations.
- Specification, algorithm development, and implementation of PC software tools to aid in flight dynamics analysis.
- Computationally efficient methods for comprehensive in-flight sensor alignment and calibration, possibly as part of the attitude determination process.
- Automated techniques for attitude sensor and actuator trend analysis and performance evaluation.
- In-flight parameter estimation for spacecraft dynamic parameters.
- Improved environmental models in order to enhance attitude sensor measurements and spacecraft dynamic simulation.

09.05 TRACKING SYSTEM FOR STS, SPACE STATION, LUNAR AND MARS MISSIONS, AND ROBOTICS
Center: JSC

Innovations are sought in microwave, millimeter-wave, and photonic-based spacecraft tracking and machine-vision systems to

support spacecraft rendezvous, station keeping, docking, proximity operations, automation, and robotics.

- A novel receiver and software to implement use of the Global Positioning System for accurate tracking and navigation during orbital-operations.
- High resolution, light-weight, low-power radar systems to solve various short-range rendezvous, station-keeping, and target-tracking problems during manned and unmanned space operations.
- A hand-held, skin-tracking LIDAR capable of directly measuring range and range rate with accuracies of 1 percent of range and 0.01 fps, respectively at distances from near-zero to 3000 ft.
- Laser and video tracking and vision sensors for autonomous and teleoperated robotics applications in rendezvous and docking operations from near-zero range up to 100 nautical miles.
- Optical sensor systems for pattern recognition, ranging, and machine vision for in-space robotic operations and Lunar/planetary landing.
- Solid state laser scanning device using no moving parts to scan a narrow laser beam rapidly and reliably over a large field of view.
- High performance, passive infrared trackers and imagers for rendezvous and proximity operations in darkness, unconstrained by ambient lighting and not requiring target illumination.
- CO_2, diode/diode array, and diode-pumped solid state LIDAR systems for range, Doppler, and bearing measurements with improvements in range, power, efficiency, eye safety, reliability, size, and mass.

09.06 SPACE STATION CREW WORKSTATION DISPLAYS AND CONTROLS
Center: JSC

The workstation design for a future Space Station must incorporate state-of-the-art display and control technologies and must provide a friendly and flexible user-machine interface. To accomplish this, innovations are needed in the following areas:

- A small-volume, low-power, multicolor, flat panel display. Currently available flat panel displays for Space Station applications offer only monochromatic capability.
- Manual input devices and mechanizations that are simple to use, employ a communication language that results in high user efficiency, and are reliable and easy to maintain.
- High-density, local workstation data storage aids such as optical disks, disk RAMs, floppy disks, bubble memory, etc.
- Compact hand controller devices with force feedback that could be used to support six degree-of-freedom master/slave type telerobotics space operations.

09.07 SPACECRAFT DATA TRANSFER USING MONOLITHIC MICROWAVE INTEGRATED CIRCUITS
Center: GSFC

NASA has a need to transfer data at increasing rates using compact hardware that consumes minimum power. Innovations are desired in the following areas for the use of monolithic microwave integrated circuits (MMICs):

- Miniature single-frequency (30 GHz), band-pass and band-stop MMIC filters, with optional varactor tuning, figures from 20 to 500, reduced noise, maximum dynamic range, fine tuning and temperature compensation.
- Small-size MMIC circulators using FET models.
- Low-loss medium power switches.
- Small, low-loss phase shifters using minimum power.

09.08 SENSOR APPLICATIONS OF MONOLITHIC MICROWAVE INTEGRATED CIRCUITS
Center: GSFC

NASA needs to develop passive sensors for space missions using synthetic aperture techniques. Innovations are desired in the

following areas for the use of monolithic microwave integrated circuits (MMICs):

- Compact, low-power correlation receivers, and other signal processing hardware with improved bandwidth.

- Millimeter wave front ends and signal processing hardware for space flight with improvements in power, weight, and size. Additional requirements include:

  - Techniques for distributing the I and Q outputs from each RF/IF module to as many 250^2 destinations;
  - Millimeter wave front ends, consisting of a mixer (with an optional RF preamplifier) and an IF amplifier, operating at RF frequencies of 23, 31, 52, 60, and 90 GHz;
  - Correlators (multiply and average functions) to process the outputs from selected pairs of the front ends; and
  - Increased bandwidth above the current 10-30 MHz upper limit.

09.09 CRYOGENIC REFRIGERATION SYSTEMS
Center: JPL

Improved active refrigeration systems for cryogenic cooling of spacecraft instruments may result from innovations for two different cooling concepts: a solid state oxygen compressor combined with a Joule-Thomson expander and a thermoelectric cooler.

In a solid state compressor, oxygen can be pressurized in a solid electrolyte cell, e.g., zirconium oxide or bismuth oxide, by applying sufficient voltage across the cell. If oxygen could be compressed to 100 atmospheres or more, it could be expanded in a Joule-Thompson refrigerator to provide cooling to liquid oxygen temperature. Innovative proposals are sought that identify electrochemical processes and demonstrate a device that could produce 100 atmosphere oxygen. Compression of other gases in a similar electrochemical device, e.g., hydrogen, also would be acceptable.

A thermoelectric cooler (TEC) is a solid state electronic cooling device that utilizes the Peltier effect to produce cooling. Multiple Peltier junctions can be fabricated to provide many watts of cooling. TECs are reasonably efficient at temperatures greater than 200 K but the efficiency drops off significantly at lower temperatures with the lowest practical operating limit about 160 K. It is desired to develop unique TEC materials that can pump heat more efficiently below 200 K and that can attain absolute temperatures below 160 K.

09.10 THERMAL CONTROL FOR UNMANNED SPACECRAFT
Center: GSFC

Future unmanned spacecraft and space facilities will operate at higher power levels, will have many more load centers at dispersed locations, and will require tighter temperature control than current space systems. Areas of innovation include, but are not limited to:

- Fluid systems technology:

  - Measurement techniques and analysis of multiphase fluid behavior and in a micro or partial gravity environment;
  - Low temperature (i.e., 100-250 K) heat pipes;
  - Heat pipe evaporator interfaces including integral heat exchangers or heat pipe disconnects;
  - Modular, self-contained heat pumps to allow equipment to operate at a temperature close to a thermal bus;
  - Long-life, no-maintenance thermal components;
  - Self diagnostic, repair, and correction subsystems;
  - Use of in situ resources for thermal storage.

- Special thermal system capabilities of interest include use of low or medium temperature waste heat to drive a cooling system; integration of the thermal and power systems to minimize total weight; and improved thermal engineering analyses techniques of actual flight temperatures.

NASA scientific goals will require instruments and facilities that operate at cryogenic temperatures ranging from 120 K down to 0.1 K or less. Areas of interest include, but are not limited to:

- Mechanical cooler technology:

  - Flexure, magnetic, and gas bearings;
  - Regenerator, including magnetic enhancement;

- Vibration-compensation, vibration-isolation, and low-vibration cooler systems;
- High reliability thermal switches;
- Magnetic cooler technology;
- Interfacing mechanical coolers with sensors.

- Stored cryogen coolers:
  - Low thermal conductance structural support systems;
  - Support systems with on-orbit release;
  - Concepts to enhance safety;
  - Innovative concepts for stored cryogen and mechanical cooler combinations.

09.11 THERMAL MANAGEMENT SYSTEMS FOR MANNED LUNAR AND PLANETARY MISSIONS
Center: JSC

Future large space systems for manned lunar or Mars missions and bases will require efficient and economical thermal management because generation, transfer, and usage of electrical energy needed for these systems will result in the dissipation of huge quantities of waste heat. Innovations are needed in heat acquisition, transport, and rejection technology in the following areas:

- A system which will take advantage of high temperature waste heat generated by the power system to raise the efficiency of rejecting room temperature waste heat from housekeeping systems.

- A system which will merge internal and external thermal control into one system by using a working fluid suitable for both external and internal cabin use.

- Innovative methods using analysis and testing on Earth to study radiative and convective heat transfer characteristics of a Mars heat rejection system.

- Revolutionary low-risk, high-payoff advanced space radiator systems compatible with high temperature heat rejection required on the lunar surface.

- A thermal management system suitable for spacecraft with spin-induced, variable, artificial gravity environment.

09.12 MANNED SPACECRAFT THERMAL SYSTEMS
Center: MSFC

Thermal systems for manned spacecraft require advanced thermodynamic, thermal, and fluid systems associated computer software. Innovations are desired in the following areas:

- Advanced heat transport systems and concepts with acceptable safety characteristics for use in manned systems.

- Two-phase evaporator and condenser components.

- Advanced interactive, user-friendly graphical techniques utilizing state-of-the-art, low-cost workstations for analysis of thermal and fluid systems.

- High-performance thermal insulation including new materials and techniques for their manufacture and application to large, uniquely shaped surfaces.
- Phase-change materials (PCM) for low temperatures (-50 °F to -100 °F) for small biological containers; and PCM components for light-weight, high-capacitance, heat rejection systems.

- Advanced techniques for low-power, thermal control systems in the area of coating and insulation systems and heater control circuitry. This area also includes advanced temperature sensing, data acquisition and transmitting devices and components.

- Long-term thermal control and storage of cryogenic or low-temperature fluids, including vapor-cooled shields, leak detection, and dewar systems.

- Integration of high-energy propulsion and power system cooling requirements with spacecraft thermal control systems including acquisition, transport, rejection, and heat-to-energy conversion subsystems.

09.13 FLUID MANAGEMENT, LEAK DETECTION, AND FIRE SUPPRESSANTS FOR MANNED MISSIONS
Center: MSFC

In order to provide a safe environment onboard Space Station *Freedom* and for later human space exploration missions, innovations

in several areas described below are solicited:

- Storage of liquids in microgravity not subject to life limitations of positive displacement bellows or bladder tanks.
- Storage and distribution of cryogenic fluids in microgravity.
- Detectors for locating and quantifying air leaks from a pressurized module during ground-based and on-orbit operations.
- Fire and smoke suppressant to minimize hazards and cleanup penalties.

09.14 SPACECRAFT PLASMA ENVIRONMENT FORECASTING
Center: ARC

Extended manned missions in space will require an accurate and continual forecast of the space plasma environment throughout the region of space in which the spacecraft will operate. This capability, including the rapid ability to warn of impending major changes, will be of paramount importance for the safety and protection of spacecraft and satellite systems as well as for the planning and optimum utilization of observational opportunities. The need is in an understanding as well as the capability to forecast the global dynamics of the space plasma and fields near Earth due to solar driven processes, especially during geomagnetic storms and substorms. The ultimate goal is to develop the capability for treating the solar-terrestrial system as a predictive system. Proposals to meet this goal include but are not limited to the following:

- Identification of the critical physical mechanisms which control energy transfer from the solar wind to the magnetosphere.
- Enhanced prediction of the effects of geomagnetic storms on the environment.
- Improved understanding of interrelationships between various regions in near-Earth space.

09.15 TECHNOLOGIES FOR LONG DURATION SCIENTIFIC BALLOONS
Center: GSFC

Successful long duration ballooning, defined as any balloon mission greater than three days, requires a system other than the normally ballasted balloon. Vented, polyethylene, "zero-pressure" balloons, with volumes up to 40 million cubic feet, maintain diurnal altitude stability through the dropping of 7-8 percent of the gross system mass. Long duration balloons capable of lifting and maintaining 3000 pound suspended loads to 130,000 feet for a minimum of 15 days require technological advancements in balloon system design, materials, fabrication, and thermal control which will offer significant improvement over existing balloon systems. Suggested areas of innovation would include but not be limited to the following:

- Thermal coatings or additives to the balloon film or structure.
- Balloon vehicle or component design to control diurnal gas pressure variation and gas loss.
- Methods to control system mass or augmentation of the lifting force.
- High strength-to-weight, heat-sealable balloon films suitable for pressurized balloon use.
- Low-cost, reliable fabrication methods for high strength-to-weight, non-heat-sealable films suitable for pressurized balloon use.

10.00 SPACE POWER

10.01 SPACE ENERGY CONVERSION SYSTEMS
Center: LeRC

Innovative concepts are solicited in the areas of dynamic and photovoltaic energy conversion for space power systems for use in manned and unmanned earth orbital and interplanetary missions, including planetary surface operations. Goals for dynamic Brayton, Rankine, and Stirling heat engine systems include low-cost, increased efficiency, decreased weight, and extended operational lifetime (7 to 10 years). Innovations are sought in:

- Single and multiphase, including linear, alternators.

- Advanced solar concentrators, heat receiver, and thermal energy storage.
- Advanced, light-weight radiators.
- Thermal management techniques.
- Bearings and methods for dealing with rotor dynamics.
- Power systems design and performance analysis methodologies.

Advancements in space photovoltaic power systems include solar cells, concentrators, array structures, deployment, and on-orbit assembly. Emphasis should be placed on innovative low-cost concepts which increase efficiency, decrease size and weight, and increase lifetime while reducing problems in manufacture and verification testing. Areas of interest are:

- Thin GaAs cells on low-cost substrates.
- Concentrator solar cells.
- Cascade cell concepts.
- Improved contacts for III-V materials.
- Micro-welding of cell interconnections.
- Advanced concepts beyond the present state-of-the-art.

10.02 OPTICAL COATING FOR AEROSPACE SOLAR CELL COVER-GLASSES
Center: GSFC

Several of NASA's future spacecraft will carry scientific instruments having liquid helium cooled detectors. In order to meet mission life requirements by minimizing the liquid helium consumption rate, the outer surface of these spacecraft must reflect incident infrared radiation. However, the same outer surface area also must be utilized for body-mounted solar cell panels to meet the spacecraft electrical power requirements. Therefore, optical filters must be developed for aerospace solar cell cover glasses to maximize reflections at wavelengths longer than the solar cell response cutoff (1.1 microns for space silicon cells and 0.9 micron for space gallium arsenide cells), while providing high transmission of light to the solar cell at wavelengths shorter than the response cutoff wavelength. It is urgent that innovative research be conducted to develop such infrared-reflecting, visible-transmitting cover-glass filters with stable properties in the charged particle radiation, ultraviolet radiation, and thermal-vacuum cycling environments of earth orbit.

10.03 THERMAL-TO-ELECTRIC CONVERSION TECHNOLOGY
Center: JPL

Reliable, long-life, high power density, space electrical power systems are needed for planetary exploration and other missions. Cost and safety issues related to the use of nuclear heat sources drive the space power system requirements for future missions well beyond the capabilities of existing technologies. Advances are needed in a number of areas of thermal to electric conversion technologies for space applications. Innovations are solicited relating to:

- Improved high temperature thermoelectric materials figure of merit values.
- Lower thermoelectric electrode contact resistance values.
- Long-life thermoelectric multicouple glass technology.
- Long-life cell materials.
- Zero-g condenser designs for AMTEC (Alkali Metal Thermal to Electric Conversion).
- Long-life electrical insulator materials for thermoelectric and/or thermionic systems.
- Alternative high efficiency/long-life direct energy conversion technologies.

10.04 PHOTOVOLTAIC-LASER ENERGY CONVERTERS
Center: LaRC

Solar-pumped lasers are promising as part of a space-based laser power system. Photovoltaic converters theoretically offer laser-to-electric conversion efficiencies approaching 50 percent if the semiconductor bandgap energy is well matched to the laser photon energy. Radiant input power densities to the converter will be as high as 1000 watts/cm^2. Innovative approaches, such as series-connected vertical multijunction converters,

may be required to minimize series resistance and to take advantage of these high power densities. Innovative crystal growth techniques, such as molecular beam epitaxy and ion implantation, may be required to grow single-crystal, series-connected, multiple p-n junction converters.

Converters of interest are $Ga_{1-x}In_xAs$ converters for use with 1.315-μm I lasers and Si converters for use with 1.06-μm Nd lasers. A converter configuration of interest is the series-connected, vertical junction converter with 500-1000 p-n junctions per cm; however, other high-risk, high-payoff concepts are also solicited.

10.05 SPACE ELECTROCHEMICAL STORAGE SYSTEMS
Center: LeRC

This subtopic concerns fuel-cell-electrolyser systems, rechargeable batteries, and other electrochemical storage systems. Component technologies for electrodes and catalysts are of interest. Proposed innovations should emphasize systems and components with increased efficiency, lifetimes, and cycling capability while reducing cost and weight and easing manufacture and checkout operations prior to use in space. Specific areas are:

- Advanced nickel-hydrogen battery systems (both primary and secondary).
- High-energy-density batteries.
- New concepts for light weight, advanced, primary and secondary fuel cells.
- Improved rechargeable, but not lithium, batteries.
- Advanced energy storage systems.

10.06 HIGH SPECIFIC ENERGY AND LONG LIFE BATTERIES
Center: JPL

Innovative research proposals are sought to develop high specific energy (100 Wh/Kg) and long cycle life (1000 cycles) ambient temperature rechargeable lithium and other advanced electrochemical systems. Areas of interest for innovations are:

- Novel approaches to improve lithium rechargeability.
- Alternate lithium anode materials.
- Stable electrolytes including polymer electrolytes.
- Improved separators.
- High specific energy cathode materials.
- Overcharge/overdischarge protection methods.
- Improved cell designs.

10.07 PORTABLE RECHARGEABLE ENERGY STORAGE FOR SPACE STATION APPLICATIONS
Center: JSC

Innovations in rechargeable energy storage concepts yielding 10-20 times the energy density of Ni-Cd batteries are needed to provide secondary power to multiple applications for Space Station *Freedom* portable equipment such as lights, data recorders, cameras, tools, scientific instrumentation and life support backpacks. Much of this equipment is used on EVAs; consequently it must be low volume and weight, and rechargeable. Long replacement intervals are needed to minimize the original weight-to-orbit requirements. Safety is also a prime consideration because most of these systems are handled directly by Space Station crewmen. Of particular interest are secondary metal-oxygen systems and thermal-voltaic (thin-film, laminated solid state metal-metal oxide cells and batteries) systems utilizing more commonly available and relatively safe, inexpensive materials such as aluminum, copper, zinc, calcium, magnesium, nickel, and graphite, rather than lithium, sulfur, and sodium. The proposed concepts should provide an energy storage building block in modular form to meet as many of the listed applications as possible.

10.08 SPACE POWER MANAGEMENT AND DISTRIBUTION
Center: LeRC
Center: MSFC

Creative concepts are desired for power management and distribution technologies for the control of high-power, high-frequency space power systems with increased autonomy in operations. Power management and distribution includes hardware (components) and software (control applications), and

state-of-the-art overall electrical system concepts that are fault and radiation tolerant and capable of high temperature operation. Areas for which new concepts are sought are:

- Materials for power electronics.
- Electronic devices, transformers, diodes, transistors, etc. for high-current, high-voltage, high-frequency power distribution systems.
- Power system fault detection and isolation and system restoration.
- Control and autonomous operation of high-voltage space power systems.
- Space environmental interactions with free oxygen, space plasma, and system-generated species materials for space-power applications.
- Thermal management and control for space power systems including advanced, lightweight heat pipes for high and low temperature operating ranges.

10.09 ELECTRICAL POWER CONTROL AND DISTRIBUTION SUBSYSTEMS
Center: JSC

Innovations in the field of aerospace electrical power distribution and control are needed in the following areas:

- Computer-controlled, high-power, solid state switching devices with self-contained instrumentation for operational readout.
- Highly efficient, lightweight, modular devices to convert dc or unregulated ac into 400 Hz regulated power.
- Innovative ways of increasing the efficiency of dc-to-dc converters in the range of 1 to 5 kW, utilizing newly available switching devices.
- Remotely actuated (mate/demate) electrical connectors which can be both mated and demated without hands-on assistance from the crew. The system must be reliable, lightweight, and simple and might involve the use of robotics.
- Highly efficient contactless alternating current connectors to aid in vehicle assembly and extra-vehicular power transmission.
- Nonintrusive ground or on-board system for early detection of degradation in the insulation of electrical wires prior to actual flight.

10.10 FLEXIBLE MAGNETIC CIRCUIT COMPONENTS FOR SPACE POWER
Center: JPL

High-frequency, switch-mode power supplies offer lower mass and volume and increased efficiency. Solid state devices can meet high frequency requirements but magnetic components do not. Using flexible printed circuit technology, magnetic components can be reduced in mass and volume and operate efficiently at higher frequencies. Inductive coil patterns (spirals) can be imprinted on a flexible board and folded in a "Z" pattern to create a densely packed coil which is fitted on a magnetic core. Innovations are solicited for magnetic components in the areas of:

- Inductors and transformers in the 20 to 500 KHz range.
- Design tool development.
- Materials and process development.
- Validation for space applications.

11.00 SPACE PROPULSION

11.01 PROPULSION SYSTEM COMBUSTION PROCESSES
Center: MSFC

Improvements are sought in the understanding of combustion processes in liquid and solid rockets. Experimental work for development and validation of improved models for combustion analysis is needed. Enhanced capabilities are sought for analytical and computational methods applicable to liquid fueled engine and solid motors in these areas:

- Simulation of the interaction of rocket nozzle flow with the ambient environment.

These numerical simulations will permit sensitivity studies of the combustion products, flow turbulence, heat transfer, boundary layer, and wall contour effects for the three-dimensional nozzle flow field. Long-range objectives include simulation of engine transient effects on the flow field.

- Modeling of the physics and chemistry of spray combustion including droplet vaporization and/or secondary breakup, droplet combustion, dense spray interactions, and flow and combustion turbulence interactions.

- Analytical models of acoustic waves in a combustion chamber with full coupling to a combustion model. The basis of this approach should be a three-dimensional computational fluid dynamical model capable of time accurate, non-diffusive simulations at time scales on the order of high frequency combustion chamber wave modes.

- Experimental studies, diagnostics, and measurement systems for validation of models of physical and chemical processes involved in combustion devices. These include atomization studies, droplet size and distribution assessments, spray combustion processes, and supercritical combustion processes.

- Computational methods for the analysis of solid motor ignition transients, including multiphase flow, grain geometries, and propellant grain ignition thermodynamics and kinetics.

- Computational methods for solid propellant burn back modeling.

11.02 LIQUID ENGINE INTERNAL FLOW DYNAMICS
Center: MSFC

To advance design and optimization of present and future liquid-fueled rocket engines, innovative techniques are sought for modeling internal flows and coupling structural and fluid dynamic behavior. Flow environments to be addressed occur in geometrically complex domains and are often unsteady and incompressible. Rotational, multiphase, multispecie, and turbulent effects also dominate and/or influence the flows to be considered. Specific areas of interest in which innovative approaches are solicited include:

- Multiblocking or zonal techniques for obtaining efficient Navier-Stokes solutions in complex three-dimensional domains.

- Analysis of incompressible, three-dimensional flow with phase change for turbopump bearing, seal, injector, and pump analysis.

- Analysis of unsteady incompressible and compressible flows over vaned elements in turbine and pump environments.

- Interfacing CAD/CAM IGES files to surface and grid generators used for structured mesh solvers for complex internal flow geometries.

- Efficient and accurate prediction of fluctuating quantities for incompressible internal flows in complex domains.

- Viscous flowfield calculation procedures to account for nonisentropic boundary layers in regeneratively cooled nozzles.

- Analysis addressing heat transfer and associated radiation levels for reacting and nonreacting flows, with emphasis on heat transfer in liquid engine combustion chambers and nozzles.

- Computational techniques for coupling three-dimensional time-dependent flow solvers to three-dimensional structural models.

11.03 SOLID ROCKET MOTOR TECHNOLOGY
Center: MSFC

Innovative concepts and approaches for design, analysis, production, and verification of solid rocket motors (SRM) are solicited:

- Improved constituent materials for nozzles (fabric, resins, etc.) and manufacturing processes.

- Approaches/techniques which can result in high reliability, low-cost cases and/or nozzles or nozzle components.

- Failure criteria for carbon-carbon and/or carbon-phenolic materials, implemented in an algorithm for predicting failure, and

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including demonstration of algorithm validity in predicting failure of specimens at high temperature and with stress to failure.

- Verification of the surface condition of cases (metal or composite), nozzle parts, liner and/or insulation prior to bonding (cleanliness, tack, etc.). Also, techniques and instrumentation for determining degree of cure in polymer insulation and liner materials.

- Precise real-time chemical analysis of continuously mixed and cast solid rocket motor propellant.

- Detection of unbonds, weak bonds, and/or "kissing" unbonds in the propellant-liner-insulation-case interfaces to a level compatible with acceptance inspection of large SRM's.

- Measurement of the thermostructural behavior (temperature and strain) of composite nozzles. Intrusive and non-intrusive instrumentation for both carbon-carbon and carbon-phenolic nozzle structures are of interest. Accurate engineering data are needed for temperatures up to 4000 °F and strain at temperatures up to at least 2000 °F. New techniques must function accurately and reliably under high heat flux and transient thermal conditions with low strain rates and be useful for validation of analytical models during hot firing.

11.04 SPACE PROPULSION SYSTEMS FOR ORBIT-TO-ORBIT AND INJECTION/ TRANSFER VEHICLES
Center: LeRC

Innovations are solicited for in-space propulsion systems. Chemical rocket propulsion systems, primarily those using hydrogen and oxygen as the propellants, and of size from 5000 pounds thrust to 200,000 pounds thrust, are of most interest. This subtopic solicits proposals for innovative concepts and techniques unique to in-space propulsion in the following areas:

- Engine system and component flow dynamics.

- Combined fluid, structural, and performance models.

- Health monitoring to ascertain the readiness of an engine stored in space for months or years to be started and operated.

- Deep throttling (20:1) in 5000 to 50,000 pounds thrust engines; modest throttling (5:1) in 50,000 to 200,000 pounds thrust engines.

11.05 UNCONVENTIONAL ROCKET ENGINES FOR ALTITUDE COMPENSATION AND THROTTLING
Center: LeRC

Launch vehicle performance can be significantly increased if altitude compensation can be provided and if throttling can be incorporated for in-flight control. Unique engine systems to provide either or both of these capabilities are being sought. It is anticipated that the concepts should minimize the impact on the remaining engine components so as to allow operation at near design conditions. The unique concepts should consider features involving nozzle, injector, or turbomachinery designs, either individually or separately to achieve the most favorable results. Specific innovations to be explored experimentally are sought.

11.06 LOW REYNOLDS NUMBER AND PLUME FLOWS
Center: LeRC

Innovations are sought in the development of improved physical models, numerical methods, and computing efficiencies for low Reynolds number and plume flows of chemical rockets. The objective is to significantly increase the accuracy and generality of theoretical analyses while decreasing their costs and requirements for arbitrary input assumptions. Specific issues of high interest include: 1) studies of the application of Boltzmann physics to plumes, nozzles, and, to the extent appropriate, combustion chamber phenomena; 2) three-dimensional reacting flows in small chemical rockets; 3) the use of plasma physics flow/stability methodologies in chemical rockets; 4) ab initio treatments of fundamental heat transfer and boundary layers; and 5) theoretical descriptions of the influence of ambient environments on nozzle/ plume phenomena.

Innovations are sought in:

- Physical models for combusting and rarefied flows, including studies to define the limits of use of Boltzmann physics.

- Numerical method/physical model trades to maximize computing speeds while maintaining required accuracies.

- Concepts to economically calculate complex, three-dimensional flows (with chemistry) in small chemical rockets.

11.07 DIAGNOSTICS FOR CHEMICAL ROCKET ENGINES
Center: LeRC

Innovative concepts are solicited which will enable direct experimental evaluation of internal flows of chemical rockets. Work is currently being performed on the application of advanced laser diagnostics to liquid rocket engine research. Phenomena of interest include: 1) boundary layers and shocks (if present) in nozzles; 2) boundary layers, mixing, and chemistry in the combustion chamber; and 3) direct observation of controlling injector phenomena. Techniques to directly observe gas and liquid velocities, droplet size, species concentration, density, and temperature inside the rocket engine injector, combustion chamber, and nozzle. Propellants of interest include, but are not necessarily limited to, both liquid and gaseous oxygen hydrogen and liquid oxygen/hydrocarbon systems. Areas of interest include:

- High temperature, high pressure, and high optical quality window materials for use in rocket engine testing.

- Measurement of flow properties in the injector subsonic and transonic regions of rocket engines.

- Microsensors for in situ temperature and pressure measurement inside the combustor without disturbing the flow.

- Methods to measure high frequency pressure oscillations in rocket engine injector tubes.

Note: Fiber optic measurement technology is included under subtopic 11.08.

11.08 FIBER OPTIC MEASUREMENT TECHNOLOGY FOR CRYOGENIC LIQUID PROPULSION SYSTEMS
Center: LeRC

In order to advance condition monitoring and control of cryogenic liquid propulsion systems, innovative sensor and multiplexed fiber optic data bus concepts are sought. The propulsion system environment is characterized by its harsh conditions. Temperatures range from that of liquid hydrogen and oxygen up to combustion products approaching 4000 °R. Pressures up to 8000 psia are encountered. Both oxidizing and reducing conditions are present. Vibration levels up to 100 Gs can be produced. Desirable features of concepts include: lightweight, high reliability, small volume, and high accuracy of measurement and data transmission in the propulsion system environment. Specific areas of interest in which innovative approaches are solicited include:

- Nonintrusive flow measurement.

- Fast response leak detection.

- In situ wear detection.

- Fiber optic sensors for pressure, temperature and flow properties in critical systems and components including combustion chambers.

- Fiber optic connector and cabling.

- Fiber optic cable feedthrough and sealing.

11.09 PROPULSION GROUND TESTING TECHNOLOGY
Center: SSC

NASA's current and future missions have driven advancements in rocket propulsion flight and launch systems. Innovative techniques are necessary in the propulsion ground testing programs at the Stennis Space Center to support these rapidly advancing technology developments, including improvements to produce more efficient operations and improvements in safety, in propulsion ground testing in support of current and future NASA missions.

This subtopic solicits proposals for innovations which would be unique to Stennis

applications and not included under other subtopics:

- Test technology capabilities.

- Testing flexibility.

- Test operation facilities and support.

- Analysis of testing operations for maximum efficiency and safety.

- Identification of propulsion ground test technologies that will support and complement NASA's current and future missions.

- Nonintrusive testing instrumentation which does not interfere with test article performance or operation:

  - Rocket plume analysis instrumentation;
  - Advanced instrumentation systems for measurement of temperature, pressure, strain, flow, vibration, liquid level, and other propulsion test data parameters;
  - Advanced data analysis and display techniques;
  - More cost effective and reliable instrumentation systems.

12.00 HUMAN HABITABILITY AND BIOLOGY IN SPACE

12.01 MEDICAL SCIENCES FOR MANNED SPACE PROGRAMS
Center: JSC

Permanent manned presence in space demands great understanding of the functioning of the human body and mind in the space environment. New technologies are essential for studies of physiology and psychology and for providing health care over extended duration missions. Because these areas of concern are very important to future NASA missions, considerable research has been and is being conducted. Therefore, it is imperative that small business proposals emphasize only new and innovative concepts which could be key to achievement of any of these objectives and which would be amenable to further development in Phase II and subsequent NASA activities.

- Methods for assessing physical conditioning and means to maintain it.

- Health diagnostic instruments and procedures.

- Imaging systems for internal body organs.

- Medical care for trauma and illness.

- Psychological assessment and treatment.

- Development of microgravity countermeasures.

- Dental care and surgery.

- Prevention and treatment of decompression sickness.

- Assessment of and protection from ionizing radiation.
- Measurement of changes in bone mineral and muscle status and development of countermeasures.

- Prediction and prevention of space motion sickness and sensory motor disturbances.

12.02 BIOMEDICAL AND ENVIRONMENTAL HEALTH SUPPORT FOR MANNED SPACE PROGRAMS
Center: JSC
Center: MSFC

Advanced manned space missions generate new requirements for a wide range of medical and biomedical activities including ground based research and development, crew support, in-flight monitoring, and in-flight investigations. To meet these requirements, innovative approaches in clinical laboratory operations, analytical chemistry, and environmental health are solicited in the following areas:

- Collection and analysis of small metabolic and biological specimens.

- Measurement of changes in immune system and quantifying stress and radiation effects.

- Estimation of circulating red blood cell mass.

- Documentation, storage and retrieval of health related clinical and laboratory diagnostic information.

- Automated, portable, multi-gas sampling gas chromatograph.

- Flameless atomic adsorption for in-flight water analysis.

- On-line monitor for near real-time measurement of microbial contamination in water in the range of 1 CFU/100ml or below.

- Automated measurement of organic constituents in reclaimed water.

- Reagentless methods to remove dissolved carbonate and separate CO_2 from solution in organic carbon analyzers without requiring the use of purge gases.

- In-flight methods and instrumentation to assess and verify physiological acceptability of recycled atmosphere and water.

- Methods for quantifying, identifying, and measuring antibiotic sensitivity measurement of microorganisms in biological and environmental specimens.

- Cultivation of eukaryotic and prokaryotic cells including cell growth, structure, and function assessment.

- Maintaining and verifying surface and equipment cleanliness within habitation and laboratory areas.

- Carbon monoxide monitoring system.

- Measurement of crew member and biological sample masses using methods other than the currently used period of oscillation.

12.03 REGENERATIVE LIFE SUPPORT: AIR, WATER, AND WASTE MANAGEMENT
Center: ARC
Center: JSC
Center: MSFC

Closure of regenerative life support systems for long-term manned missions is essential for the success of future manned planetary explorations. The requirements for the development of the physicochemical and integrated, physicochemical/biological closed-loop, life support systems include: micro and partial gravity operation; high reliability; the elimination of expendables; and low system weight. Considerations are to include bio-regenerative processes and associated hardware, sensors, and instrumentation to accomplish basic life support system functions of air revitalization, water reclamation and waste management. Innovations are sought in the following areas:.

- Air Revitalization:

  - O_2 and CO_2 concentration, separation, and control techniques (e.g., O_2 recovery from Martian atmosphere);
  - Gas-phase separation of CO_2 from a mixture primarily of N_2, O_2, and water vapor to maintain concentrations of CO_2 below 0.4 percent by volume;
  - Gas-phase separation of N_2 from CO_2 to reduce concentrations of N_2 to less than 0.2 percent by volume;
  - Improved sorbent beds using activated carbon or other sorbents for trace contaminant removal;
  - Improved catalyst for high-temperature, catalytic, oxidation of trace contaminants (organics) as an alternative to expendable adsorption and chemical sorption techniques.

- Water Reclamation:

  - Efficient, direct treatment of waste water (e.g., urine, wash water, and condensates) by processes not using any expendables to provide potable and hygiene water;
  - Stabilization of waste waters prior to storage and/or processing and of waste purge gases prior to overboard venting without the use of expendable materials;
  - Potability maintenance (processed water handling and treatment) techniques;
  - In situ cleaning and sterilization of potable water systems.

- Waste Management:

  - Stabilization of wastes and recovery of useful products (e.g., N_2, H_2, CO_2) from organic waste materials;
  - Treatment of laboratory, metabolic and other wastes for storage;
  - Microbial techniques for waste treatment in micro or partial gravity.

- Filters and Filter Technology.

In responding to the above areas, theoretical analyses and a discussion of the intended application, proposed innovation principles,

and experimental data that support the proposed concept must be provided.

12.04 BIOREGENERATIVE FOOD PRODUCTION
Center: ARC
Center: KSC

Bioregeneration of oxygen, food, and water will reduce the need for resupply and will increase the potential duration and extent of planned missions with human beings in orbit and on flights to and on the surfaces of the Moon and Mars. Innovations are needed in subsystems that will function in micro and variable gravity for growing crop plants, processing materials into foods, waste processing, and controlling the system. Components must have minimum mass and volume and consume little power. Requirements for human intervention and replacements of parts must be reduced. Among the areas for innovation are the following:

- Sensing devices for O_2, CO_2, humidity, dissolved and volatile organic matter, microbial populations and compositions, and plant nutrients.

- Identification of volatile and soluble organic substances produced by plants in air, transpired water, and recirculating hydroponic solutions.

- Monitors and controls for pH, water levels, flow, salinity, turbidity, electrical conductivity, and nutrient composition.

- Means for determining plant growth and photosynthetic and respiratory gas exchange.

- Alternate methods to provide light for plants including bright LEDs; solar light collection, transmission, and diffusion; and high efficiency electrical lighting.

- Utilization of waste heat and humidity and transpired water for bioregenerative processes.

- Processing wastes and inedible biomass (cellulose) into foods for human consumption.

- Automated, robotic, and computer-vision systems for crop seeding, cultivation, harvesting, biomass separation, and food processing.

- Techniques for growing plants with special capabilities (tissue culture and genetically improved plant materials).

- Automated biological tissue sampling and preservation.

- Color, IR, spectrophotometric, and fluorescence camera systems for monitoring plants in closed chambers.

12.05 HUMAN FACTORS FOR SPACE CREWS
Center: ARC
Center: JSC
Center: MSFC

Space human factors must be improved so as to optimize crew performance and productivity. Innovative devices and techniques are required to enhance crew operations under all space flight conditions and to facilitate the design of crew habitats and human-to-systems interfaces for both zero-g and reduced-g environments.

- Means to acquire anthropometric and biomechanical kinematics and dynamic data to optimize human performance in space and to use in applied design models for space flight.

- Techniques for providing data and models of human perceptual and cognitive processes for use in the development of intelligent systems for space applications.

- Enhanced human interfaces with telerobotic and automated devices.

- Efficient lighting sources for general and task illumination that are lightweight, utilize minimum power, provide high lumen output per watt, and are safe for in-flight use.

- Methods to define, reduce, modify and/or control the acoustic environment in a spacecraft, particularly in the speech communications frequencies, with consideration given to weight and volume penalties.

- Layout, arrangement, and decor of spacecraft interiors to promote effective and efficient use of both the zero-g and partial-g environments in carrying out living and working tasks.

- Modular approaches to the buildup of zero-g and partial-g crew areas, stressing capability for on-board reconfigurations and modifications and associated interfacing, support, and handling equipment.

12.06 INTRA-VEHICULAR SYSTEMS FOR SPACE CREWS
Center: JSC

Extended duration manned missions create needs for new systems designed to increase the performance and productivity of the flight crews and also have positive influences on their physical and mental well-being. Innovations are desired in the following crew equipment areas with emphasis on concepts promising greater utility, efficiency, and value.

- Crew hygiene systems for male and female body and hair grooming, oral cleansing, and shaving under microgravity and closed environmental systems conditions.

- Temporary solid trash handling systems for collecting, deodorizing, storing, and packaging of paper, food scraps, and other solid trash.

- Equipment tracking and management systems to enhance the tracking, stowage, and inventory management of crew equipment and supplies.

- Electronic photography systems and components to enhance and augment high resolution electronic photography for space flight applications.

- Data transmission means for providing uplink, downlink, display, storage, and archival of images and data.

- Improved imagery systems and techniques to make images more dimensionally correct and eliminate the foreshortening effects of conventional telephoto systems (improve depth perspective).

- Visual observation means to provide high resolution observation from intra-vehicular viewing stations and windows of targets and activities from manned vehicles.

- Enhanced food systems for extended missions including techniques adaptable to a microgravity environment for packaging, preparation, and serving solid and liquid foods.

- Techniques and methods for extending the shelf life of fresh fruits and vegetables.

12.07 EXTRA-VEHICULAR ACTIVITY
Center: ARC
Center: JSC

Increasing use of extra-vehicular activity (EVA) mandates innovations to improve effectiveness. Solutions must be compact, lightweight, and reliable. Proposals are solicited in various areas. Examples include:

- Venting or non-venting cooling concepts for Lunar/Martian environments.

- Techniques for low-power vapor and/or CO_2 removal and regeneration from EMU ventilation loop.

- Very lightweight construction materials and processes for space suit and life support systems that resist corrosion, have 15 - 30 year lifetimes (without leeching unwanted materials into the life support fluids), and withstand abuse of working in a Lunar/Martian gravity environment.

- Space suit hardware design and production approaches for higher operating pressure EVA gloves, highly durable insulation material layups, and liquid cooling garments.

- EVA work site aids and assembly techniques for precise alignment, mating, tool positioning and storage, illumination, and tethering. Methods for fastening, joining, cutting and drilling metallic and non-metallic materials with collection of particle debris. Methods for splicing, cutting, joining and forming of electrical cables and fluids plumbing.

- Quantity gaging/sensing system for cryogenic subcritical liquid O_2 storage for gravity or zero gravity environments.

- Analysis techniques for fabric structures and space suit bearing seal performance.

- Chemical oxygen system approaches for an emergency oxygen backup for breathing and pressure maintenance in the space suit.

- Astronaut rescue system which is simple, carried by an EVA crew member and capable of retrieving an adrift object or disabled EVA crew person.

- Fusible materials for thermal control of portable life support systems.

12.08 HUMAN FACTORS FOR LONG DURATION SPACE MISSIONS
Center: ARC

Future space missions may last several years during which humans must be able to function effectively and productively. Crew systems and procedures need to be developed to maintain safe and productive human performance during and after missions. Innovations needed for long duration manned missions include:

- Real-time signal processing for spectrally shaping auditory signals, head- and body-tracking systems, and head-mounted, high-resolution, wide-angle, visual displays to meet crew information requirements.

- Displays, controls, information management, and other techniques to facilitate crew management of on-board systems, extra-vehicular systems and robots.

12.09 MAN-SPACE SYSTEMS INTEGRATION
Center: MSFC

Man-Space Systems Integration (MSI) applies the systems approach during development to enhance human well-being and system performance. Thus, the limitations and capabilities of the human operator must be considered in forming an effective, symbiotic Man-Machine System (MMS). Optimization of the MMS is accomplished through the systematic application of relevant data, principles, and practices of MSI to the design of equipment, operations, and systems. Areas of required innovation include:

- Techniques for determining and modeling relaxed body posture, dynamic work envelopes, force requirements and capabilities, and specifications for body-restraints and mobility-aids in micro-g and partial-g environments.

- Models for time to perform tasks and the consumption of oxygen and other materials in micro-g and partial-g environments based on data collected in simulated micro-g and partial-g environments.

- Small, lightweight input and output devices that can be attached to a user's body (e.g., monitors, keyboards, hand-controllers, joysticks, etc).

- Communication systems that enhance discrimination among and intelligibility of several simultaneous sources, (e.g., providing the user the perception that the sources are spatially separated in three dimensions).

- Providing information on system output using alternate sensory modes (i.e., non-visual). Examples include non-speech auditory displays and force-reflective hand-controllers.

- A computational technique to evaluate the illumination parameters of a design concept represented by a CAD database using real-time, computer-generated animation. Parameters include glare, luminance ratios, shadows, etc. These should be related to an eye reference position (ERP) that can move in three dimensions and consider the shadows produced by the head and body associated with the ERP.

12.10 LIFE SCIENCES SPACEFLIGHT TECHNOLOGY
Center: ARC

Life science payloads provide basic scientific information on the response of living systems to the space environment as well as possible explanation of the human response and adaption to space. Innovation is sought in areas which will enhance or enable the full flight experiment potential of unicellular organisms, animals and plants through improved care, support, observation, and monitoring techniques for the Space Station.

- Implant telemetry for direct biosystem monitoring or control.

- General improvement in nonhuman, physiological monitoring for in-flight and ground studies of cardiovascular, skeletal, vestibular, hematological, reproductive, and other changes occurring during spaceflight.

- Environmental control and monitoring systems applicable to various species for

maintenance of desired temperature, humidity, vibration, atmosphere, and other factors during spaceflight.

- Application of various techniques and hardware to zero-g conditions, such as animal holding and husbandry facilities, incubators, surgical techniques, wet chemistry processing, biochemical analysis, and continuous flow processing for aerobic and anaerobic fermentation.

12.11 MINIATURE BIOMEDICAL TELEMETRY INSTRUMENT
Center: KSC

A miniature biomedical telemetry instrumentation system is needed to allow the collection of accurate field (in situ) data to assess factors of physiologic consequence, such as heat stress. This system should be capable of collecting a wide range of parameters including ECG, skin temperatures, suit temperatures, body core temperature, oxygen takes, CO_2 productions, respiration rate, blood pressure, and voice. The system should be miniature to avoid adding yet another encumbrance to the protective equipment being worn. Telemetry must allow real-time assessment and monitoring by investigators who may be nearby but outside the immediate hazardous area. The system could have application to a wide variety of ground support and space activities.

12.12 ONE-ATMOSPHERE-PRESSURE UNDERWATER SUIT
Center: MSFC

Currently, underwater testing at the Neutral Buoyancy Simulator Complex is limited by SCUBA diving tables. The objective of this subtopic is to solicit innovations for a one-atmosphere-pressure hard suit which will avoid this limitation and will significantly increase available test time under neutral bouyancy conditions. The hard underwater suit will also increase the safety of operations since the test subject will no longer be exposed to extreme pressure conditions. Also, because the suit will be designed specifically for underwater use, operating and maintenance costs will be greatly reduced. The following characteristics for the one-atmosphere-pressure suit are desired:

- The ability of the suit to simulate motion of a crewman wearing the existing flight suit.

- A "hard" or "semi-hard" glove for the suit that can function properly at depths of up to 60 feet.

- Materials compatible with chlorinated water.

13.00 QUALITY ASSURANCE, SAFETY, AND CHECK-OUT FOR GROUND AND SPACE OPERATIONS

13.01 HALON REPLACEMENT FOR USE IN ELECTRONIC FACILITY FIRE PROTECTION SYSTEMS
Center: KSC

NASA is soliciting technology innovations leading to the identification, development and test of a candidate safe fire extinguishing agent to replace Halon 1301 for electronic facility fire protection systems. Current Halon 1301 fire extinguishing systems use total flooding to treat the entire room. Gas is applied to the entire protected space, wall-to-wall and floor-to-ceiling. These systems comply with the National Fire Codes, NFPA 12A (Halon 1301 Fire Extinguishing Systems).

The replacement agent must have little or no ozone depletion indices, perform in microgravity environments and provide comparability to Halon 1301 in fire protection and personnel safety. Additionally, the agent must leave no residue.

It is highly desirable that the replacement agent be compatible with currently installed Halon 1301 equipment systems, and that the agent not require complex modifications or major redesign of installed fire protection systems.

The chemical kinetics of a replacement agent's fire suppression ability must be demonstratable.

Water will not be considered a candidate replacement agent.

13.02 PORTABLE INDUCTIVE WELDER WITH INTEGRAL WELD VERIFICATION
Center: KSC

Intensive test and check-out of STS flight hardware often reveals a need for the field repair and inspection of assembled fluid systems.

Innovative designs are solicited to reduce costs and processing turnaround times associated with the field repair/replacement of system components which are welded in place in space launch systems and ground systems.

A self-contained portable induction welder for welding tubing and pipe that also performs the weld verification without the use of off-line shops or labs would increase Shuttle processing efficiency. Weld integrity verification is presently accomplished by time-consuming and expensive x-ray inspections.

13.03 LAUNCH AND GROUND WEATHER FORECASTING
Center: KSC

New and innovative concepts are solicited to improve and enhance weather forecasting in support of shuttle operations. Areas of interest include:

- Reliable assessment of the threat of triggering lightning by launch vehicles during ascent and the shuttle orbiter during descent:
  - Assessing the perturbing of the atmospheric electric field by the rising vehicle and its exhaust;
  - Assessing the charging of the vehicle by triboelectrification;
  - Remote sensing and modeling of electrical characteristics of clouds and neighboring atmosphere in the vicinity of the launch trajectory;
  - Characterization of the triggered flash for design purposes.
- Thunderstorm probability forecasts: windows of 1/2 hour to 24 hours with a lead time of 1/2 hour to 72 hours:
  - Forecasts for specific work complexes (diameters up to 4 miles) as well as the whole of KSC;
  - Forecast performance assessment;
  - Improved exploitation of existing instrumentation.
- Forecasting of diffusion, transport, and reactions of toxic substances and improvements in verification techniques.
- Facility lightning protection assessment. Methods are required to assure specific levels of lightning protection related to actual protected system susceptibilities:
  - Computer modeling of current flow in facility lightning protection systems;
  - Expert systems for use on CAD/CAE systems to validate design rules and design;
  - Sensors to measure the electromagnetic environment within facilities housing hardware susceptible to induced effects.
- Lightning detection:
  - Lightning detectors suitable for attachment to large surfaces, both conductive and nonconductive, to detect and characterize lightning effects;
  - Detecting and locating lightning within 40 miles with an accuracy of one mile.

13.04 FLUIDS AND FLUID SYSTEMS COMPONENTS
Center: KSC

Concepts are solicited in the area of low maintenance, high reliability fluid system components used in liquid, gaseous and cryogenic systems. These innovative designs are desirable to reduce costs associated with installation and maintenance and minimize ground operations turnaround times for space launch systems and ground systems. Examples of innovations include:

- Helium regulator valves which by innovation in the design of the location, shape or size of the seat, or innovation addressing the seat material, will not be subject to failure from temperature excursions caused by the expanding gas.
- Innovations are also sought which address the on-site purification/production of high purity refrigeration grade ammonia (NH_3) and high purity liquid oxygen (LO_2F):
  - A high purity grade of liquid oxygen (LO_2F) is required to support the Shuttle's on board fuel cell system.

LO_2F is produced by a limited number of air separation plants in the US. When the product is shipped and stored, it is prone to go out of specification due to a condition known as "methane enrichment." A means to produce LO_2F economically, on-site, would eliminate availability concerns and provide a more reliable supply for meeting projected increasing demands for LO_2F;

- A high purity grade of NH_3 required to support the Shuttle's on board cooling system. The present Shuttle grade NH_3 (fluid specification SE-S-0073) is furnished by a sole source supplier.

  Because the annual use of NH_3 at KSC is only about 3000 pounds, there is little incentive for companies to produce this product. A means to produce Shuttle grade NH_3 economically, on-site, from refrigeration grade NH_3 would eliminate availability concerns and reduce costs for supply.

13.05 FLOWMETER TEST AND CALIBRATION
Center: MSFC

This subtopic solicits proposals for innovative instruments, techniques and procedures for testing and calibrating liquid and gas flowmeters. Flowmeter calibration will be at conditions of extreme temperature and pressure and will be at, or near, the critical flow conditions of the fluids. Requirements include:

- Capability of testing and calibrating venturi, turbine and orifice plate flowmeters.
- Flowmeter sizes from 1 in. to 10 in. nominal pipe diameter.
- The fluids will consist of liquid hydrogen, liquid oxygen, RP-1 (kerosene), gaseous hydrogen, gaseous nitrogen and gaseous helium.
- Pressure range up to 1000 Atm.
- Temperature range from -423 °F to 100 °F.
- Incorporation of liquid recovery systems.

13.06 TEST FACILITY INSTRUMENTATION AND SAFETY DEVICES
Center: JSC

Testing of space flight and ground components at the NASA White Sands Test Facility requires state-of-the-art devices to support operations. Areas of potential innovation include:

- Contamination Detection: (1) A reliable and traceable method of calibrating commercial airborne particle monitors by verifying the size and number of particles; (2) a non-contact instrument that quickly determines the quantity of organic contamination on small, inaccessible metal surfaces; (3) a near real-time method to determine non-volatile residue or hydrocarbon contamination on a component surface.
- Toxic Propellant Detection: Develop techniques to detect parts per billion concentrations of hydrazine, monomethylhydrazine, ammonia, and nitrogen tetroxide on the surface of space suits and equipment in a vacuum and in ambient pressure air.
- Propellant Composition Change Detection: Develop sensors to detect real-time concentration changes of typical impurities (halides, carbon dioxide, decomposition products, dissolved metals) in hydrazine, monomethylhydrazine, and nitrogen tetroxide.
- High Speed Gas Thermometer: Develop a high speed (microseconds) nonintrusive means of measuring the adiabatic gas temperature (to 2000 °F) due to pneumatic impact of high pressure oxygen (to 10,000 psi).
- Dynamic Pressure Sensor: Develop a technique to measure the near-field dynamic pressure in a free blast environment. Blast intensity range: 10 kg TNT equivalent. Response time: less than a microsecond.
- Rapid Decontamination of Personnel Protective Equipment (PPE): Develop economical techniques to rapidly decontaminate PPE exposed to hypergolic propellants.

13.07 QUALITY ASSURANCE OF VERY LARGE SCALE INTEGRATED (VLSI) CIRCUITS
Center: JPL

Future highly autonomous spacecraft will use custom integrated circuits to increase mission duration and spacecraft autonomy. Such integrated circuits must operate as specified and be tested cost-effectively before launch to assure fault-free operation during the mission. VLSI design analysis systems should encompass the following activities:

- Support an implementation of the VHSIC hardware description language (VHDL) in accordance with the IEEE 1076 standard.
- Provide stuck-at fault simulation with 99 percent (or better) fault coverage, delay fault simulation and multiple simultaneous fault simulation of a 100 K gate circuit complexity within several hours.
- Identify the failure modes that exist in the fabrication process, their corresponding fault models and determine appropriate testing methods.

13.08 NONDESTRUCTIVE EVALUATION INSPECTION TECHNIQUES FOR LAUNCH READINESS VERIFICATION
Center: KSC

Innovative methods of on-line verification of launch readiness of critical flight hardware are needed to enable rapid and safe turnaround and reuse of STS flight elements. The methods would be used in a field environment during preflight processing of assembled flight elements. Because many of the flight and payload components are very sensitive to some forms of energy, the proposed nondestructive evaluation (NDE) methods must consider potential side effects on flight hardware, payloads or personnel located in the near proximity.

Typical objectives would be to detect the onset of such phenomena as stress corrosion or hydrogen embrittlement in critical attachment hardware and delamination, unbonding or moisture gradients in non-metallic materials and detection of fluid system leaks.

The detection of fluid system leaks (gaseous hydrogen, helium and oxygen for example) during preflight preparation as soon as they occur is of special interest. This preflight leak checking is currently accomplished manually. New approaches are needed to provide automated means of verifying zero preflight leakage.

Proposed hardware solutions should be relatively portable and be adaptable to automated use under computer and/or robotic control.

14.00 SATELLITE AND SPACE SYSTEMS COMMUNICATIONS

14.01 COMMUNICATIONS FOR MANNED SPACE SYSTEMS
Center: JSC

Multiple, simultaneous links will be required to communicate among the variety of elements within the National Space Transportation System, Space Station *Freedom*, Lunar, and Mars systems, including satellites and extra-vehicular astronauts. Areas of significant innovative potential include:

- Advanced multiple beam antennas with near-hemispherical coverage at Ku-, Ka-, W-band, and optical frequencies for supporting simultaneous multiaccess users.
- Personal communication systems: multiple users, user access and remote controls, distributed antennas system, and portable data terminals.
- Active transmit/receive elements using monolithic microwave integrated circuit technology at Ku/Ka-band frequencies.
- Solid state text and graphics consisting of 4,000+ individual light sources capable of illuminating corresponding points along a horizontal scan line.
- Generalized mathematical models and integrated software packages to allow simulation and evaluation of the performance of communication systems.

- Small size, lightweight, digital, solid state imaging, display, and processing systems are needed. High definition for large scenes, high grey-scale resolution, and data compression of higher order with quality imagery.

- Automated monitoring and management of communication resources including scheduling, fault diagnosis, and fault recovery to satisfy real-time communication requirements.

- Communication systems for telerobotic devices must simultaneously provide multiple channels of high quality video, high rate data, and command/control signals with a minimum two-way time delay control.

14.02 ADVANCED DATA RELAY SATELLITE SYSTEMS
Center: GSFC

NASA's next generation data relay satellites require capabilities which exceed those currently achievable. They require laser transmitter and receiver technology which will permit data transfer from low Earth orbit to geosynchronous orbit with rates exceeding 300 MBits/sec, and communications across the geosynchronous arc at rates of 2 gbits/sec or greater. Innovations are required in several areas:

- High average power (type 1-5 Watts) diode pumped Nd:YAG laser transmitters are needed to increase the performance while reducing the size and weight of optical communication terminals. Single transverse mode structure, linear polarization, high efficiency and small size are needed for satellite applications.

- Small lightweight external modulators are required which can impress either phase or amplitude modulation on the Nd:YAG laser output at rates approaching 2 gbits/sec. Innovations in modulator design are required to minimize their required electrical drive voltage, to extend their modulation bandwidth, to improve their optical transmission, and to extend their optical power handling capability.

- GaAlAs diode lasers are also being developed for use in free space optical communication systems. High performance solid state modulator drivers are needed; subnanosecond rise and fall times and 0.5 to 1.0 Ampere currents are required to support the high data rate signals.

- More efficient implementation of the electronics in optical communication terminals is needed; application specific integrated circuit (ASIC) technology will likely permit significant power, size, and weight reductions. Functions which are candidates for ASIC implementations include bit synchronizers, data processors such as multiplexers/demultiplexers, parallel-serial converters, psuedo-random noise (PRN) code generators, and acquisition and tracking electronics.

14.03 MILLIMETER WAVE DEEP SPACE COMMUNICATIONS COMPONENTS
Center: JPL

Increasingly sophisticated scientific instrumentation aboard advanced deep space missions has generated a demand for high data transmission rates to Earth. Most deep space missions operate near 8 GHz, but these data rate demands may be more economically met by utilizing the 32 GHz downlink and 34 GHz uplink frequency bands (Ka) allocated by the FCC.

New techniques are needed for monolithic microwave integrated circuit (MMIC) phased array distribution systems for millimeter waves including: digital control and power signals; thermal control; integrated circuit, hermetically sealed packaging; high-efficiency, solid state, microwave discrete and monolithic integrated circuit transmitter components; transponder components; computer-aided design tools; array beam control; and signal distribution system technology for phased arrays. Innovations are solicited for:

- Design and fabrication of high-efficiency ($\approx$30 percent), high power ($\approx$0.25 W) Ka-band and higher frequency MESFET, HEMT and pseudomorphic HEMT devices with submicron gate lengths suitable for MMIC applications.

- Low-noise amplifier device designs and low-loss components to 100 GHz, including high temperature superconductor devices and components.

- Methods of distribution of millimeter wave, digital signals and dc power in phased array systems.

- Repeatable, well characterized, hermetically sealed packages for microwave integrated circuits at 32 GHz. These packages must be capable of being interfaced with microstrip or coplaner waveguide transmission line at 32 GHz and with power and digital control circuitry.

14.04 SPACECRAFT TELECOMMUNICATION SYSTEMS
Center: JPL

Future spaceborne communication transponders require high-speed digital signal processing (DSP) and detection techniques to downconvert and process Ka, Ku, X, and S-band signals.

Innovative application and integration of MMIC and DSP circuits are solicited to implement high-performance space communication receivers to provide carrier tracking, command and ranging capabilities. Typical performance requirements are:

- Input frequencies: 34.2 to 34.4 GHz; and 13.6 to 14 GHz; 7.1 to 7.3 GHz, 2.1 to 2.2 GHz.

- Input signal level range: -156 to 70dBm.

- Reference frequency: 20 to 120 MHz.

- IF frequencies, selected by external filters: 47 to 1300 MHz.

- Temperature range: -20 °C to +75 °C.

Advanced concepts for MMIC low-noise system fabrication, packaging, and radiation cooling are required to allow hardware location near the spacecraft antenna. The stand-alone packaged MMIC LNAs must provide low noise and high gain for the specified frequency ranges. Performance requirements are:

- Input frequencies: Ka-band 34.2 to 34.4 GHz, Ku-band, 13.6 to 14 GHz; X-band, 7.1 to 7.3 GHz.

- Effective noise temperature (ambient = 290 K): Ka-band <250 K, Ku-band <110 K, X-band <75 K).

- Gain: 30 dB ± 0.4 dB.

- Input signal level: -156 to -70 dBm.

- Operational temperature environment: -185 °C to +85 °C .

14.05 ADVANCED SATELLITE COMMUNICATIONS SYSTEMS
Center: LeRC

Advanced concepts are required for devices, components, and subsystems that support advanced civil applications. All allocated frequencies are of interest with particular emphasis at Ka band and above. Proposals applicable to uplinks, downlinks, or inter-satellite links are sought.

- MMIC, discrete solid state, or free electron concepts for components and subsystems which stress higher frequency of operation or improvement in bandwidth, power, efficiency, noise figure, gain, reliability, size, or cost.

- Flexible, fault tolerant, high speed, on-board routing (data, packet, or message) systems, including autonomous control through knowledge-based systems, to meet the throughput and interconnectivity needs of advanced communications networks.

- Novel electronic or optical implementation of power and bandwidth efficient modems with 650 MBPS to 1.3 GBPS throughput for on-board applications. Digital signal processing concepts and components that enable FDMA channel demodulation and decoding with a single device.

- Cost-reducing digital concepts and components for ground terminals in systems using FDMA uplink and TDM downlink. Includes acquisition, synchronization, self-test and fault tolerance, reliability, and compatibility with standard terrestrial interfaces.

- Novel approaches for producing multiple, scanned, transmitting or receiving beams from a single MMIC phased array feed. Interests include new architectures, new concepts in MMIC packaging, and utilization of optical/photonic technologies.

- Image data compression techniques, lossy or lossless, that achieve significant bit rate reductions.

14.06 OPTICAL COMMUNICATION FOR DEEP SPACE
Center: JPL

Future deep space exploration spacecraft will use optical frequencies to communicate back to near-Earth orbit or directly to the ground. Numerous innovations will be required to facilitate these new systems. Innovative concepts are needed for:

- Developing lasers which have high power conversion efficiency (approximately 10 percent), produce single and stable far-field beam profiles, and which can be easily modulated using a pulse position modulation format with high peak pulse energies (0.1 mJ).
- CW laser sources are needed for heterodyne systems which produce very stable output frequencies, as are design approaches and concept verifications for coherent optical transponder functions.
- The narrow beamwidths require accurate pointing and focal plane detector arrays which have the ability to provide pointing information electronically, but the readout rates of the arrays may limit the overall spatial tracking bandwidth. Innovations are needed for high gain, focal plane detector arrays with electronically-controlled cursor readout. A kHz readout rate (with single or multiple pixel), a gain of million, and a responsiveness better than an S-20 photocathode are desired.
- For detection of such optical signals, large aperture (greater than 5 meters in diameter), inexpensive, non-diffraction-limited optical reception telescopes for use on the ground or in space will be required. Reception wavelengths for these "photon buckets" are in the 0.5 to 1.2 micron region. Concepts and design verifications also are sought for using such telescopes at small angles off the solar limb (i.e., at small Sun-Earth-spacecraft angles).

14.07 LOW COST KA-BAND GROUND TERMINALS
Center: LeRC

The Advanced Communications Technology Satellite (ACTS) currently under development is an experimental satellite that uses time division multiple accessing (TDMA) together with on-board switching and multiple narrow hopping beam antennas to route communications traffic among a network of small user Earth stations. The master control facilities necessary to manage a network of Earth stations also are currently under development. Innovations are needed to develop low-cost, transmit/receive experimenter terminals to function with this satellite. These terminals initially will not need to address the TDMA aspects of the ACTS system but will operate with burst modems and controllers through an IF interface.

Innovative concepts to achieve these objectives are solicited, with particular reference to the following areas and devices. Offerors are advised not to submit proposals which suggest design or development based on well-known or conventional devices which could be obtained through normal specification procurements.

- 30 GHz transmitters in the 10W to 20W range.
- 2.5 m diameter antennas.
- Upconverters (IF to 30 GHz).
- Downconverters (20 GHz to IF).
- Low noise receivers at 20 GHz.
- IF interface to burst modems at burst rates of 27.5 and 110 Mbps.
- Beacon receivers at 20 GHz for propagation measurements.

14.08 LASER POSITION MODULATORS FOR OPTICAL COMMUNICATIONS
Center: JPL

Innovative research is required to provide efficient, low power modulators to drive electro optic Q-switches for modulation of future deep space laser communication systems. Innovative packaging and encapsulation techniques are required to provide good volumetric efficiency, while achieving state-of-the-art performance for long life (12 years) deep space missions. The research effort should show feasibility for achieving the following goals for modulator characteristics: demonstrate repetition rates up to 25 kHz for generation of high voltage pulses (1-3 kV),

with goals of rise and fall times of 1-3 ns. The modulator should be capable of driving high capacity (20 pF), Q-switch technology for laser modulation.

15.00 MATERIALS PROCESSING, MICROGRAVITY, AND COMMERCIAL APPLICATIONS IN SPACE

15.01 MATERIALS PROCESSING IN SPACE
Center: LERC
Center: MSFC

Opportunities for commercial processing of materials exist in the low gravity of space. Innovations are sought for the following:

- Materials:
  - Electronic materials, semiconductors, and solid-state detectors used in electronics, computers, communications, and medical instrumentation;
  - Metallic alloys with improved grain structures by directional solidification and processing involving supercooling and undercooling states;
  - Glasses, ceramics, and optical fibers by containerless processing to eliminate impurities, to control nucleation sites, and to process reactive melts;
  - Biological materials, specific cell types, cell components, hormones, antigens, proteins, and other organic and crystalline substances with greater purity and throughput;
  - Crystallization of proteins for structure determination and other properties;
  - Electro-optical materials, organic and inorganic, for applications in photonics.

- Technological phenomena, techniques, and equipment:
  - Experimentational and computational methods for thermodynamic and fluid process in weightlessness including multiphase flows in a complex regime of thermal and solute gradients as affected by the weightlessness conditions of space. These flows affect processes of crystallization, separation, solute-solvent, glass, and other solidification and phase-change phenomena;
  - Processing techniques; acoustic, electromagnetic and electrostatic levitation; continuous-flow electrophoresis; isoelectric focusing; cell culture and deposition; furnaces of all types; combustion processes; isotachophoreses; surface tension manipulation; instrumentation and control procedures; and characterization of materials.

15.02 MICROGRAVITY SCIENCE, TECHNOLOGY AND ENGINEERING EXPERIMENTS
Center: LeRC

Innovations leading to the definition and development of in-space experiments and equipment required for quality space laboratory experimentation on micro-gravity processes/phenomena and spaceflight technologies are solicited. Areas of interest in microgravity science and applications are the fundamental sciences, including fluids and transport phenomena and combustion science, and the materials sciences, including metals, alloys, electronic materials, glasses, and ceramics. Spaceflight technology and engineering areas include energy conversion and space power systems, fluid and thermal management systems, space environmental effects, and spacecraft fire safety.

Spaceflight experiments utilize the Space Shuttle, free-flyers, and eventually, Space Station *Freedom*. The definition and development of hardware to accommodate space experiment investigators is an ongoing NASA activity. Ground-based experimentation to provide short-duration low-gravity science and/or definition of spaceflight experiments, is accommodated in unique government research facilities which are available at the NASA Lewis Research Center. Up to 5 seconds of low-gravity time can be obtained in drop facilities. The Micro-gravity Materials Science Laboratory provides easy access and assistance to investigators from industry, universities, and government wishing to conduct materials research using spaceflight-type experimental equipment.

Innovative advancements are needed to enable or enhance space experiment apparatus development in the areas of instrumentation and sensors, data recording and storage, property measurement techniques, waste product disposal systems, unique mechanical devices, advanced furnace technology and

materials, sample preparation techniques, automation/process control, nonintrusive diagnostics, and acceleration/vibration environmental control. Of particular interest are proposals emphasizing innovative applications.

15.03 CHEMICAL VAPOR DEPOSITION ANALYSIS AND MODELING TOOLS
Center: LaRC

Chemical vapor deposition is one of the key technologies of the electronics industry. To foster development, it is essential that predictive models be developed to compare the results of early micro-gravity testing with scientific theory and ground-based empiricism. Prediction of the fundamental fluid flow and reaction phenomena taking place under varying gravity fields requires innovations in computational methodology. This subtopic seeks innovative development of a general-purpose fluid flow simulation program that predicts in three spatial dimensions the mass, temperature, momentum, energy, and chemical species distributions during the chemical vapor deposition of electronic materials, and presents the results in both tabular and graphical formats. Innovations are especially critical in the treatment of compressible fluids in high thermal gradients, of particulate nucleation and growth in the fluid, of time- varying source materials, and of time-varying reactor movement due to large-scale low- frequency vibrations.

APPENDIX F

251 PROPOSALS SELECTED BY NASA IN 1989 FOR SBIR PHASE I AWARD

NO.	TOPIC	COMPANY NAME	CITY & STATE	PROJECT TITLE
1	01	SCIENTIFIC RESEARCH ASSOC	GLASTONBURY, CT	FLOW IN TURBINE BLADE PASSAGES
2	01	PROGRAM DEVELOPMENT CORP	WHITE PLAINS, NY	TURBO: A GRID GENERATION CODE WITH AUTOMATIC ZONING
3	01	PHYSICAL SCIENCES INC	ANDOVER, MA	REACTION MECHANICS AND KINETIC RATES FOR SOOT FORMATION
4	01	MOLLER INTERNATIONAL INC	DAVIS, CA	EVALUATION OF PS200 COATING AS A THERMAL BARRIER IN AN AIR-COOLED ROTARY ENGINE
5	01	CFD RESEARCH CORPORATION	HUNTSVILLE, AL	RAPID MIX CONCEPTS FOR LOW EMISSION COMBUSTORS IN GAS TURBINE ENGINES
6	01	ISG ASSOCIATES INC	ANAHEIM HILLS, CA	INFLUENCE OF TOOTH PROFILE MODIFICATION ON THE LUBRICATION OF INVOLUTE GEARING
7	01	DELTA G CORP	SUN VALLEY, CA	HIGH TEMPERATURE HOSTILE ENVIRONMENT INSTRUMENTS MANUFACTURED BY CVD
8	01	PHYSICAL SCIENCES INC	ANDOVER, MA	LASER-INDUCED FLUORESCENCE MEASUREMENTS OF VELOCITY IN SUPERSONIC REACTING FLOWFIELDS
9	01	TEKNOWLOGICA INC	PRINCETON JUNCTION, NJ	NON-INTRUSIVE SINGLE POINT PRESSURE/TEMPERATURE SENSOR FOR AERONAUTICAL PROPULSION APPLICATIONS
10	01	FOA ENGINEERING	CHEVY CHASE, MD	HIGH-EFFICIENCY FLOW INDUCTION
11	02	APPLIED & THEORETICAL MECHANICS	OAKLAND, CA	TWO EQUATION TURBULENCE MODELING OF HYPERSONIC TRANSITIONAL FLOWS WITH UPS CODE
12	02	AMTEC ENGINEERING INC	BELLEVUE, WA	COUPLING GRID ADAPTION TO AN IMPLICIT NAVIER-STOKES SOLUTION PROCEDURE
13	02	CREARE INC	HANOVER, NH	ADVANCED MODELING OF COMBUSTION SYSTEMS
14	02	ATLANTIC APPLIED RESEARCH	BURLINGTON, MA	WIND TUNNEL NOISE REDUCTION
15	02	NEKTONICS INC	CAMBRIDGE, MA	TRANSITION TO TURBULENCE IN COMPLEX AERODYNAMIC FLOWS
16	02	ENGINEERING ANALYSIS INC	HUNTSVILLE, AL	CALCULATION OF SURFACE PRESSURE FLUCTUATIONS BASED ON TIME-AVERAGED TURBULENT FLOW COMPUTATIONS
17	02	METROLASER	IRVINE, CA	A HOLOGRAPHIC INTERFEROMETER SPECTROMETER FOR HYPERSONIC FLOW
18	02	DEACON RESEARCH	PALO ALTO, CA	REMOTE MEASUREMENT SYSTEM FOR ARC JET TEMPERATURE AND DENSITY
19	02	HANSEN RESEARCH ASSOCIATES	EUGENE, OR	TRANSPORT PROPERTIES IN NON-EQUILIBRIUM AIR MIXTURES
20	02	PHYSICAL SCIENCES INC	ANDOVER, MA	HIGH VELOCITY GAS SURFACE ACCOMMODATION
21	02	NIELSEN ENGINEERING & RESEARCH	MOUNTAIN VIEW, CA	A MODEL FOR SHOCK TURBULENCE INTERACTION
22	02	REMTECH INC	HUNTSVILLE, AL	COUPLING OF UNSTEADY FLUID DYNAMICS AND STRUCTURE IN LOW DENSITY HIGH SPEED FLOWS
23	02	EIDETICS INTERNATIONAL INC	TORRANCE, CA	AERODYNAMIC CONTROL OF THE F/A-18 USING FOREBODY VORTEX BLOWING
24	02	ADVANCED TECHNOLOGIES INC	NEWPORT NEWS, VA	SOFT HUB FOR BEARINGLESS ROTORS
25	02	JOHNSON AERONAUTICS	PALO ALTO, CA	GENERAL TIME-DOMAIN UNSTEADY AERODYNAMICS OF ROTORS
26	02	INFORMATION & CONTROL SYSTEMS	HAMPTON, VA	A HIGH-TEMPERATURE DIRECTIONAL SPECTRAL EMISSIVITY MEASUREMENT SYSTEM
27	02	AMERICAN RESEARCH CORP OF VA	RADFORD, VA	CROSS-CORRELATION OPTICAL STRAIN SENSOR FOR WIND TUNNEL TEST INSTRUMENTATION
28	02	CONTINUUM DYNAMICS INC	PRINCETON, NJ	GENERAL FLOW FIELD ANALYSIS METHODS FOR HELICOPTER ROTOR AEROACOUSTICS
29	02	ENGINEERING ANALYSIS INC	HUNTSVILLE, AL	THE APPLICATIONS OF FRACTIONAL CALCULUS TO NOISE SIMULATION
30	02	AEROCHEM RESEARCH LABORATORIES	PRINCETON, NJ	COMPUTER SIMULATION AND DESIGN OF JET NOISE SUPPRESSORS
31	03	ELECTROIMPACT INC	SEATTLE, WA	EDDY CURRENT REPULSION DE-ICING STRIP
32	03	STODDARD-HAMILTON AIRCRAFT	ARLINGTON, WA	LIGHTNING PROTECTION TECHNOLOGY FOR SMALLER GENERAL AVIATION AIRCRAFT
33	03	EIDETICS INTERNATIONAL INC	TORRANCE, CA	AN IMPROVED METHODOLOGY TO ASSESS DEPARTURE SUSCEPTIBILITY VS. AGILITY
34	03	SCIENTIFIC SYSTEMS INC	WOBURN, MA	REAL-TIME ADAPTIVE IDENTIFICATION AND PREDICTION OF FLUTTER
35	03	ANALYTICAL SERVICES & MATERIALS	HAMPTON, VA	FLIGHT INSTRUMENTATION FOR SIMULTANEOUS DETECTION OF FLOW SEPARATION & TRANSITION
36	03	INNOVATIVE DYNAMICS	ITHACA, NY	LOW COST ANGLE-OF-ATTACK SENSOR FOR SUBSONIC AIRCRAFT

NO.	TOPIC	COMPANY NAME	CITY & STATE	PROJECT TITLE
37	03	AMERICAN RESEARCH CORP OF VA	RADFORD, VA	LASER SPECKLE INTERFEROMETER FOR SURFACE ACOUSTIC DISPLACEMENT MEASUREMENTS
38	03	B&D INSTRUMENTS AND AVIONICS	VALLEY CENTER, KS	EVALUATION OF PVDF FILM AS A PRESSURE SENSOR
39	03	REFRACTORY COMPOSITES INC	WHITTIER, CA	CERAMIC MATRIX COMPOSITE HYPERSONIC ENGINE STRUCTURES
40	03	DIESELDYNE CORP	MORROW, OH	AN ADVANCED HEAT REJECTION SYSTEM FOR AN AVCD ENGINE IN A HIGH ALTITUDE RESEARCH PLATFORM
41	03	AURORA FLIGHT SCIENCES CORP	ALEXANDRIA, VA	FUEL CELL PROPULSION SYSTEM FOR A HIGH ALTITUDE RESEARCH PLATFORM
42	03	ACA INDUSTRIES INC	PALOS VERDES, CA	STUDY OF VERY-HIGH-ALTITUDE AIRCRAFT WITH JOINED WINGS
43	03	SEARCH TECHNOLOGY INC	NORCROSS, GA	METHODS AND TOOLS FOR ASSESSING LIMITS OF SYSTEM INTELLIGENCE
44	03	G & C SYSTEMS INC	DANA POINT, CA	A KNOWLEDGE BASED SIMULATION DESIGN, DEVELOPMENT AND CODING ENVIRONMENT
45	04	MATERIALS & ELECTROCHEMICAL RES	TUCSON, AZ	A COATED, TITANIUM BORIDE, WHISKER-TOUGHENED SILICON CARBIDE MATRIX COMPOSITE
46	04	FOSTER-MILLER INC	WALTHAM, MA	HIGH-TEMPERATURE-FILM BASED POLYBENZOXAZOLE/POLYMIDE MICROCOMPOSITE FOR TURBINE ENGINES
47	04	GUMBS ASSOCIATES INC	EAST BRUNSWICK, NJ	SOLUBLE CONDUCTING POLYMER-BASED CONDUCTIVE COATINGS
48	04	APPLIED RESEARCH ASSOCIATES	RALEIGH, NC	PROBABILISTIC STRUCTURAL MECHANICS RESEARCH FOR PARALLEL PROCESSING COMPUTERS
49	04	FOSTER-MILLER INC	WALTHAM, MA	LARC-TPI/LIQUID CRYSTAL POLYMER BLENDS
50	04	TEXTILE TECHNOLOGIES INC	HATBORO, PA	MULTI-ANGULAR WEAVING FOR COMPOSITE PREFORMS
51	04	HIGH TECHNOLOGY SERVICES INC	TROY, NY	METHODS FOR PRODUCING FINE PARTICLE THERMOPLASTIC POLYIMIDE SULFONE POWDER
52	04	ULTRAMET	PACOIMA, CA	CVD CHROMIUM DIBORIDE FIBERS FOR METAL MATRIX COMPOSITES
53	04	RIBBON TECHNOLOGY CORP	GAHANNA, OH	RAPIDLY SOLIDIFIED NARROW TITANIUM ALUMINIDE STRIP
54	04	CORDEC CORPORATION	LORTON, VA	MICROSTRUCTURALLY TOUGHENED INTERMETALLIC MATRIX COMPOSITES
55	04	CSA ENGINEERING INC	PALO ALTO, CA	DEVELOPMENT OF ADVANCED FINITE ELEMENTS FOR STRUCTURAL ANALYSIS
56	04	SYSTEMS & PROCESSES ENG	AUSTIN, TX	DIGITAL OPTICAL PHASE-LOCK-LOOP FOR NON-DESTRUCTIVE EVALUATION
57	04	INNOVATIVE DYNAMICS	ITHACA, NY	AIRCRAFT HEALTH MONITORING SYSTEM
58	04	JOHN M. COCKERHAM & ASSOCIATES	HUNTSVILLE, AL	PORTABLE SPECTROREFLECTOMETER
59	04	RIBBON TECHNOLOGY CORP	GAHANNA, OH	PROCESS CONTROL FOR MELT OVERFLOW RAPID SOLIDIFICATION TECHNOLOGY
60	04	CFD RESEARCH CORPORATION	HUNTSVILLE, AL	A MATHEMATICAL MODEL TO INVESTIGATE UNDERCUTTING AND TO OPTIMIZE WELD QUALITY
61	04	AUTOMATIX INC	BILLERICA, MA	MACRO AND TASK-LEVEL PROGRAMMING OF ARC WELDING ROBOTS FOR AEROSPACE APPLICATIONS
62	04	EXFLUOR RESEARCH CORPORATION	AUSTIN, TX	NEW PERFLUOROPOLYETHER ELASTOMERS FOR LOW AND HIGH TEMPERATURES
63	04	CAPE COD RESEARCH INC	BUZZARDS BAY, MA	IMPROVED ELECTRO-RHEOLOGICAL FLUIDS FOR LUBRICANT VISCOSITY CONTROL
64	04	FARE INC	HYATTSVILLE, MD	A COMPOSITE MATERIAL FLYWHEEL FOR ENERGY STORAGE
65	04	ISM TECHNOLOGIES INC	SAN DIEGO, CA	MINIATURE THIN FILM DEPOSITION SYSTEM
66	04	CORDEC CORPORATION	LORTON, VA	NEW FABRICATION METHODS FOR DIMENSIONALLY STABLE GRAPHITE/MAGNESIUM SPACE STRUCTURES
67	04	SATCON TECHNOLOGY CORP	CAMBRIDGE, MA	MAGNETOSTRICTIVE ACTIVE MEMBER FOR CONTROL OF SPACE STRUCTURES
68	04	SATCON TECHNOLOGY CORP	CAMBRIDGE, MA	DIRECT MEASURMENT OF BOLT TENSION UTILIZING MAGNETOSTRICTION
69	04	MATERIALS & ELECTROCHEMICAL RES	TUCSON, AZ	A WHISKER REINFORCED HIGH TEMPERATURE STRUCTURAL INSULATION
70	04	ADVANCED DIVERSFIED TECHNOLOGY	SAN DIEGO, CA	PROTECTIVE COATINGS FOR COMPONENTS USED IN SPACE
71	04	APA OPTICS INC	BLAINE, MN	ATOMIC LAYER CVD OF YTTRIUM-BARIUM-CUPRATE OVER A LOW DIELECTRIC SUBSTRATE
72	04	SUPERCONDUCTOR TECHNOLOGIES	SANTA BARBARA, CA	IN SITU THALLIUM FILMS BY LASER ABLATION

APPENDIX F - 251 PROPOSALS SELECTED BY NASA IN 1989 FOR SBIR PHASE I AWARD

NO.	TOPIC	COMPANY NAME	CITY & STATE	PROJECT TITLE
73	04	RADIATION MONITORING DEVICES	WATERTOWN, MA	HIGH FIELD, HIGH Tc SUPERCONDUCTING MAGNETS
74	04	ADVANCED TECHNOLOGY MATERIALS	NEW MILFORD, CT	NOVEL PROCESS FOR THE THIN FILM GROWTH OF YTTRIUM-BARIUM-CUPRATE
75	04	NEOCERA ASSOCIATES INC	PISCATAWAY, NJ	MICROWAVE-COMPATIBLE HIGH-Tc SUPERCONDUCTING FILMS ON SAPPHIRE SUBSTRATES
76	04	CPS SUPERCONDUCTOR CORP	MILFORD, MA	ULTRARAPID TEXTURED GROWTH OF YTTRIUM-BARIUM-CUPRATE FILAMENTS FOR COMPOSITE HTSC WIRE
77	04	CASTLE TECHNOLOGY CORP	WOBURN, MA	INCREASING CRITICAL CURRENT DENSITIES IN HIGH-Tc SUPERCONDUCTORS
78	04	EMEC CONSULTANTS	EXPORT, PA	PRODUCTION OF OXYGEN BY ELECTROLYSIS OF LUNAR SOIL IN MOLTEN SALT
79	04	CONSTRUCTION TECHNOLOGY LABS	SKOKIE, IL	FEASIBILITY STUDY FOR LUNAR CEMENT PRODUCTION
80	05	DIGITAL SIGNAL CORPORATION	SPRINGFIELD, VA	WAVELENGTH DIPLEXED, FIBER COUPLED, COHERENT LASER RADAR MEASUREMENT SYSTEM
81	05	AMERICAN INNOVISION INC	SAN DIEGO, CA	IDENTIFYING, LOCATING AND TRACKING OBJECTS BY DETECTING PRE-AFFIXED COLORED TARGETS
82	05	SARCOS RESEARCH CORP	SALT LAKE CITY, UT	HIGH PERFORMANCE MULTIAXIS STRAIN SENSING
83	05	PHOTON RESEARCH ASSOCIATES	SAN DIEGO, CA	INTEGRATED ERGONOMIC SYSTEM SOFTWARE DEVELOPMENT
84	05	INTELLIGENT AUTOMATION INC	ROCKVILLE, MD	TELEROBOT CONTROL INTERFACE BASED ON CONSTRAINTS
85	05	BARRETT DESIGN INC	BOSTON, MA	A WRIST USING NEW MECHANISM TECHNOLOGY INVENTED FOR WHOLE-ARM MANIPULATION
86	05	BEGEJ CORPORATION	LITTLETON, CO	GLOVE CONTROLLER WITH FORCE AND TACTILE FEEDBACK FOR DEXTEROUS ROBOTIC HANDS
87	05	CARNEGIE GROUP INC	PITTSBURGH, PA	AN EXPERT ADVISOR FOR FAILURE MODE AND EFFECTS ANALYSIS GENERATION
88	05	DYNAMIC MICROSYSTEMS	GOLETA, CA	A VLSI 3-DIMENSIONAL PROCESSOR FOR ADVANCED ROBOTIC MANIPULATION
89	05	DYNAMIC MICROSYSTEMS	GOLETA, CA	A PRECISE FORCE CONTROLLED ROBOTIC SYSTEM
90	05	KMS FUSION INC	ANN ARBOR, MI	GLOBAL-LOCAL ENVIRONMENT TELEROBOTIC SIMULATOR
91	05	UNIQUE MOBILITY INC	ENGLEWOOD, CO	ROBOTIC ACTUATOR OPTIMIZATION
92	05	FOSTER-MILLER INC	WALTHAM, MA	SELF-CONTAINED DEPLOYABLE SERPENTINE TRUSS FOR PRELAUNCH ACCESS OF ORBITER PAYLOADS
93	05	TRANSITIONS RESEARCH CORP	DANBURY, CT	TORTUOUS-PATH ROBOT TRANSPORT
94	05	ACCURATE AUTOMATION CORP	CHATTANOOGA, TN	ADVANCED TELEROBOTIC CONCEPTS USING NEURAL NETWORKS
95	05	COMPUTER ALGORITHM DEVELOPMENT	AUSTIN, TX	ACTIVE DETECTION AND TRACKING SENSOR FOR PASSIVE TARGETS
96	06	GALLOWAY RESEARCH	SAN JOSE, CA	THE LAFS KERNEL FILE SYSTEM
97	06	COLORADO RESEARCH DEVELOPMENT	DENVER, CO	PARALLEL MULTILEVEL ADAPTIVE METHODS FOR FLOWS IN TRANSITION
98	06	SOFTWARE PRODUCTIVITY SOLUTIONS	MELBOURNE, FL	CASE VISUALIZATION SYSTEM
99	06	IRVINE SENSORS CORPORATION	COSTA MESA, CA	THREE-DIMENSIONAL SOLID STATE MULTI-PORT MEMORY SYSTEM
100	06	ODYSSEY RESEARCH ASSOCIATES	ITHACA, NY	FORMAL VERIFICATION FOR C WITH UNIX
101	06	SPEECH SYSTEMS INC	TARZANA, CA	SITE-SPECIFIC AIR TRAFFIC CONTROL TRAINING SIMULATOR WITH SPEECH INPUT & OUTPUT
102	06	KESTREL DEVELOPMENT CORP	PALO ALTO, CA	SEMI-AUTOMATIC DATA STRUCTURE SELECTION
103	06	ISX CORP	THOUSAND OAKS, CA	KNOWLEDGE BASED AEROSPACE PROGRAM MANAGEMENT DECISION SUPPORT SYSTEM
104	06	SOFTWARE PRODUCTIVITY SOLUTIONS	MELBOURNE, FL	PASSIVE KNOWLEDGE ACQUISITION SYSTEM
105	06	TOGAI INFRALOGIC INC	IRVINE, CA	DEVELOPMENT OF FUZZY-CLIPS EXPERT SYSTEM
106	06	ASSOCIATED DYNAMICS INTL	BEVERLY HILLS, CA	KNOWLEDGE NETWORKS FOR MISSION PLANNING AND FLIGHT CONTROL
107	06	DATAFLOW COMPUTER CORP	BOSTON, MA	PROGRAM MAPPING STRATEGIES FOR MULTIPROCESSOR COMPUTERS
108	06	DEMOGRAFX	CULVER CITY, CA	APPLICATION OF HIGH PERFORMANCE DIGITAL VIDEO TO COMPUTER STORAGE

APPENDIX F - 251 PROPOSALS SELECTED BY NASA IN 1989 FOR SBIR PHASE I AWARD

NO.	TOPIC	COMPANY NAME	CITY & STATE	PROJECT TITLE
109	06	MICROWAVE MONOLITHICS INC	SIMI VALLEY, CA	ADVANCED OPTICAL HEAD TECHNOLOGY
110	06	DIMENSION TECHNOLOGIES INC	ROCHESTER, NY	A HIGH RESOLUTION AUTOSTEREOSCOPIC DISPLAY
111	06	MIMD SYSTEMS INC	BELMONT, CA	A DISTRIBUTED OBJECT-ORIENTED DATA FACILITY FOR LOCAL MEMORY PARALLEL COMPUTERS
112	07	OPTIVISION INC	DAVIS, CA	A PROGRAMMABLE IMAGE DATA COMPRESSION SUBSYSTEM FOR WORKSTATIONS
113	07	VEXTRA CORP	BOULDER, CO	HIRIS-ORIENTED VISUALIZATION SOFTWARE SYSTEM
114	07	OPTIVISION INC	DAVIS, CA	A HYBRID SIMULATION SYSTEM FOR IMAGE DATA COMPRESSION
115	07	TECHNOLOGY INTERNATIONAL	LAPLACE, LA	APPLICATION OF FRACTALS TO SMOOTHING OVER THE PARAMETER SPACE
116	07	TERASTAR	SANTA BARBARA, CA	GEOGRAPHIC INFORMATION SYSTEMS AND LARGE SPATIAL DATABASES
117	07	AUTOMETRIC INC	ALEXANDRIA, VA	IMPROVED ACCESSING OF DIGITAL DATA BASES BY GEOGRAPHIC INFORMATION SYSTEMS
118	07	SPATIAL INFORMATION SCIENCES	STENNIS SPACE CTR, MS	RASTER AND VECTOR DATA INTEGRATION, INTERACTIVE EDIT AND ANALYSIS
119	07	PHOTONIC SYSTEMS INC	MELBOURNE, FL	WIDEBAND MULTI-CHANNEL ACOUSTO-OPTIC SPECTROMETER FOR RADIO ASTRONOMY APPLICATIONS
120	07	EPITAXX INC	PRINCETON, NJ	VISIBLE SEMICONDUCTOR DIODE LASERS GROWN BY HYDRIDE VAPOR PHASE EPITAXY
121	07	GENERAL PURPOSE MACHINES LAB	IRVINE, CA	A NEURAL NETWORK DYNAMIC SEQUENCER FOR DISTRIBUTED MISSION PLANNING AND CONTROL
122	07	REI SYSTEMS	MCLEAN, VA	A DISTRIBUTED OBJECT TYPE MANAGEMENT SYSTEM FOR HETEROGENEOUS ENVIRONMENTS
123	07	NONVOLATILE ELECTRONICS INC	EDINA, MN	ULTRA-DENSE MAGNETRORESISTIVE MASS MEMORY
124	08	EPITAXX INC	PRINCETON, NJ	A 128 X 128 ELEMENT INDIUM-GALLIUM-ARSENIDE IR DETECTOR ARRAY AT 300K
125	08	ADVANCED TECHNOLOGY MATERIALS	NEW MILFORD, CT	NOVEL MERCURY CADMIUM TELLURIDE GROWTH PROCESS
126	08	QUANTEL INTERNATIONAL	SANTA CLARA, CA	DIODE-PUMPED SHORT-PULSE LASER FOR RANGING AND ALTIMETRY
127	08	SPACE INSTRUMENTS INC	ENCINITAS, CA	CLOUD TOP RADIOMETER
128	08	INTERDISCIPLINARY SCIENCE APPL	ROCKVILLE, MD	A STOCHASTIC RAIN MODEL AND ITS APPLICATION IN RAIN RATE ESTIMATION
129	08	SCHMIDT INSTRUMENTS INC	HOUSTON, TX	VERY LARGE SCALE INTEGRATION TIME INTERVAL UNITS
130	08	PHOTON RESEARCH ASSOCIATES	CAMBRIDGE, MA	MULTISPECTRAL REMOTE SENSING USING SPRITE TECHNOLOGY
131	08	SCHWARTZ ELECTRO-OPTICS INC	ORLANDO, FL	NOVEL COBALT-DOPED MAGNESIUM FLUORIDE LIDAR FOR AEROSOL PROFILER
132	08	RESSLER ASSOCIATES INC	LAUREL, MD	AN AIRBORNE LASER DEPOLARIZATION IMAGING SENSOR FOR TERRESTRIAL MEASUREMENTS
133	08	LIGHT AGE INC	WARREN, NJ	SINGLE LONGITUDINAL MODE ALEXANDRITE LIDAR TRANSMITTER
134	08	SCIENCE & ENGINEERING SVCS	SILVER SPRING, MD	SYSTEMS FOR CONTINUOUS TUNING AND SINGLE MODE OPERATION OF SOLID STATE LASERS
135	08	SCHWARTZ ELECTRO-OPTICS INC	CONCORD, MA	LASERS OPTIMIZED FOR PUMPING TITANIUM-ALUMINA LASERS
136	08	SPIRE CORPORATION	BEDFORD, MA	DEVELOPMENT OF 780NM AND 792 DIODE LASER PUMPS FOR SOLID STATE LASERS
137	08	SCIENCE RESEARCH LABORATORY	SOMERVILLE, MA	COMPACT, LIGHTWEIGHT EXPANDING BEAM CO2 LASER AMPLIFIERS FOR SPACEBOARD APPLICATIONS
138	08	ELECTRO-OPTICS TECHNOLOGY INC	FREMONT, CA	MULTIPLE DIODE PUMPED Ho:Tm:YAG PLANAR RING LASER
139	08	IRVINE SENSORS CORPORATION	COSTA MESA, CA	SPACE SENSOR COMMON MODULE ELECTRONICS
140	08	MILLITECH CORPORATION	SOUTH DEERFIELD, MA	A BROADBAND MULTICHANNEL PRECIPITATION SENSOR
141	08	ARACOR	SUNNYVALE, CA	MINIATURE BIOGENIC ELEMENT ANALYZER
142	08	AOTF TECHNOLOGY INC	SUNNYVALE, CA	ADAPTIVE RAPID SCANNING IMAGING SPECTROPOLARIMETER
143	08	MATERIALS TECHNOLOGIES CORP	MONROE, CT	NOVEL MATERIAL AND FABRICATION TECHNOLOGY FOR HIGH PRECISION LIGHTWEIGHT OPTICS
144	08	EIC LABORATORIES INC	NORWOOD, MA	EFFICIENT FAR-INFRARED INDUCTIVE MESH FILTERS BY PHOTOELECTROCHEMICAL ETCHING

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NO.	TOPIC	COMPANY NAME	CITY & STATE	PROJECT TITLE
145	08	OPTRON SYSTEMS INC	BEDFORD, MA	LOW-COST IMAGING ELECTRON MULTIPLIER DEVICE
146	08	PHOTOMETRICS LIMITED	TUCSON, AZ	BACKSIDE-ILLUMINATED, LARGE FORMAT CHARGE-COUPLED DEVICES AND MOSAICS
147	08	INFRARED FIBER SYSTEMS INC	SILVER SPRING, MD	INFRARED FIBER ARRAYS FOR LOW BACKGROUND INFRARED ASTRONOMY
148	08	CENTER FOR REMOTE SENSING	MCLEAN, VA	IMPROVED ANTENNA FOR SYNTHETIC APERTURE RADAR CALIBRATOR
149	08	SETS INC	MILILANI, HI	MULTICHANNEL OCCULTATION PHOTOMETER
150	08	SETS INC	MILILANI, HI	ATMOSPHERIC OPACITY MONITOR
151	08	AURORA ASSOCIATES	MOUNTAIN VIEW, CA	WIDEBAND ACOUSTO-OPTIC SPECTRA ANALYZER
152	08	INTERFEROMETRICS INC	VIENNA, VA	DUAL K AND C BAND TRANSPONDER FOR SATELLITE ALTIMETRIC CALIBRATION
153	08	AURORA ASSOCIATES	MOUNTAIN VIEW, CA	ACOUSTO-OPTIC TUNABLE FILTER
154	08	SCHMITT TECHNOLOGY ASSOC	NEW HAVEN, CT	GAS JET DEPOSITION OF OPTICAL THIN FILMS FOR EXTREME ULTRA-VIOLET AND SOFT X-RAY APPLICATIONS
155	08	BARR ASSOCIATES INC	WESTFORD, MA	ION BEAM DEPOSITION OF LARGE AREA, LOW SCATTERING METAL COATINGS
156	08	EIC LABORATORIES INC	NORWOOD, MA	PHOTOETCHED ECHELLE GRATINGS IN SILICON
157	08	TMA TECHNOLOGIES INC	BOZEMAN, MT	BROADBAND SOURCE DEVELOPMENT FOR A THREE-DIMENSIONAL REFLECTOMETER
158	08	SCHMIDT INSTRUMENTS INC	HOUSTON, TX	TIME-OF-FLIGHT MASS SPECTROMETRY INSTRUMENTS FOR MONITORING CONTAMINANTS IN SPACE
159	08	APPLIED RESEARCH CORPORATION	LANDOVER, MD	HIGHLY TRANSPARENT AND RUGGED SENSOR FOR METEOROIDS AND SPACE DEBRIS
160	08	PANAMETRICS INC	WALTHAM, MA	CRYOGENIC ULTRASONIC MASS FLOWMETER AND QUALITY METER
161	09	INTEGRATED SYSTEMS INC	SANTA CLARA, CA	CONTROL STRUCTURE INTERACTION: OPTIMIZATION BASED DESIGN TOOLS
162	09	SPACEBORNE INC	LA CANADA, CA	A HIGH-SPEED, FAULT-TOLERANT MICROPROCESSOR FOR SPACE APPLICATIONS
163	09	CHARLES RIVER ANALYTICS INC	CAMBRIDGE, MA	A NEURAL NET APPROACH TO SPACE VEHICLE GUIDANCE
164	09	SCS TELECOM INC	PORT WASHINGTON, NY	A NOVEL DIRECTION-FINDING TECHNOLOGY FOR ROBOTIC TRACKING IN THE SPACE STATION
165	09	PHYSICAL OPTICS CORP	TORRANCE, CA	DYNAMIC, COHERENTLY COUPLED, HOLOGRAPHIC OPTICAL ELEMENTS USING LIQUID CRYSTAL
166	09	FOSTER-MILLER INC	WALTHAM, MA	NOVEL COMPOSITES FOR PROTECTION AGAINST ORBITAL DEBRIS
167	09	WINZEN INTERNATIONAL INC	SAN ANTONIO, TX	AUTOMATED SEAL FLAW DETECTION
168	09	TRACER TECHNOLOGIES INC	SOMERVILLE, MA	A LOW-THERMAL-CONDUCTIVITY CONNECTOR
169	09	HITC SUPERCONCO INC	NEW HOPE, PA	HIGH TEMPERATURE SUPERCONDUCTOR PASSIVE MAGNETIC BEARING
170	09	MICROCOSM INC	TORRANCE, CA	SPACECRAFT ATTITUDE DETERMINATION USING AI AND ATTITUDE MEASUREMENT INFORMATION THEORY
171	09	OPTRON SYSTEMS INC	BEDFORD, MA	LOW-VOLTAGE THIN-FILM ELECTROLUMINESCENT PHOSPHOR
172	09	APA OPTICS INC	BLAINE, MN	FLAT PANEL MULTICOLOR DISPLAY BASED ON INTEGRATED OPTIC SCANNER
173	09	QUANTA INC	SMYRNA, GA	UNIVERSAL BILATERIAL ROBOTIC CONTROLLER
174	09	ROCKY RESEARCH	BOULDER CITY, NV	HIGH-DENSITY, CHEMICAL THERMAL STORAGE SYSTEM FOR LOW GRAVITY ENVIRONMENTS
175	09	FOSTER-MILLER INC	WALTHAM, MA	HEAT PUMP FOR SPACE THERMAL BUS
176	09	CREARE INC	HANOVER, NH	MAGNETIC BEARINGS FOR MINIATURE HIGH SPEED TURBOMACHINES
177	09	STIRLING TECHNOLOGY COMPANY	RICHLAND, WA	A HIGH EFFICIENCY, LOW VIBRATION, LONG LIFE, STIRLING CRYOGENIC PRE-COOLER
178	09	THERMACORE INC	LANCASTER, PA	SINTERED POWDER, ARTERY-FREE WICKS FOR LOW TEMPERATURE HEAT PIPES
179	09	ROCKY RESEARCH	BOULDER CITY, NV	HIGH-LIFT, HEAT-ACTUATED, SOLID-VAPOR HEAT PUMP FOR SIMULTANEOUS REFRIGERATION AND WATER HEATING
180	09	CREARE INC	HANOVER, NH	CONDENSER COMPONENT DESIGN FOR ALKALI METAL THERMOELECTRIC CONVERSION SYSTEMS

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NO.	TOPIC	COMPANY NAME	CITY & STATE	PROJECT TITLE
181	09	THERMACORE INC	LANCASTER, PA	COMPOSITE MATERIAL HEAT PIPE TECHNOLOGY
182	09	HUNTSVILLE SCIENCES CORP	HUNTSVILLE, AL	FINITE-ELEMENT/ADAPTIVE GRID THERMAL ANALYZER WITH ENHANCED GRAPHICS CAPABILITY
183	09	REMTECH INC	HUNTSVILLE, AL	INTEGRATED CAD VENTING ANALYSIS PACKAGE
184	10	SATCON TECHNOLOGY CORP	CAMBRIDGE, MA	INTEGRATED POWER AND ATTITUDE CONTROL SYSTEM FOR THE SPACE STATION AND OTHER APPLICATIONS
185	10	IOWA THIN FILM TECHNOLOGIES INC	AMES, IA	FLEXIBLE, LIGHTWEIGHT AMORPHOUS SILICON SOLAR CELLS TUNED FOR AMO SPECTRUM
186	10	ADVANCED ENERGY TECHNOLOGY INC	POWAY, CA	NEW THERMIONIC CONVERTER FOR OUT-OF-CORE SPACE POWER SYSTEM
187	10	ENERGY SCIENCE LABS INC	SAN DIEGO, CA	COMPOSITE REGENERATOR FOR STIRLING ENGINE
188	10	HYDROGEN CONSULTANTS INC	LITTLETON, CO	CONSTANT TEMPERATURE HEAT STORAGE IN METAL HYDRIDES
189	10	WILSON GREATBATCH LTD	CLARENCE, NY	RECHARGEABLE LITHIUM/TITANIUM DISULFIDE CELLS WITH LONG CYCLE LIFE
190	10	GINER INC	WALTHAM, MA	NICKEL-CADMIUM BATTERY SEPARATOR DESIGN AND DEVELOPMENT
191	10	SPIRE CORPORATION	BEDFORD, MA	VERTICAL, MULTIJUNCTION, PHOTOVOLTAIC CELLS WITH BURIED SILICIDE INTERCONNECTIONS
192	10	MICON ENGINEERING	COLLEGE STATION, TX	INTELLIGENT PROTECTION SYSTEM FOR SPACE POWER APPLICATIONS
193	10	EIC LABORATORIES INC	NORWOOD, MA	ROBUST HIGH Tc RIBBON FOR POWER TRANSMISSION
194	11	AEROMETRICS INC	SUNNYVALE, CA	SIMULTANEOUS MEASUREMENT OF TEMPERATURE, SIZE, AND VELOCITY OF DROPS IN SPRAYS
195	11	ACCEL CATALYSIS INC	IOWA CITY, IA	A CATALYTIC THERMAL MANAGEMENT SYSTEM FOR HYDROGEN-FUELED INJECTION VEHICLES
196	11	ELECTROFORMED NICKEL INC	CORONA, CA	HIGH TEMPERATURE OXIDATION BARRIER COATINGS FOR REFRACTORY METALS
197	11	SCIENTIFIC RESEARCH ASSOCIATES	GLASTONBURY, CT	AN EULERIAN-LAGRANGIAN ANALYSIS FOR LIQUID FLOWS WITH VAPOR BUBBLES
198	11	SECA INC	HUNTSVILLE, AL	HEAT TRANSFER IN ROCKET ENGINE COMBUSTION CHAMBERS AND REGENERATIVELY COOLED NOZZLES
199	11	ALABAMA CRYOGENIC ENGINEERING	HUNTSVILLE, AL	ORTHO-PARA CONVERSION IN SPACE-BASED HYDROGEN DEWAR SYSTEMS
200	11	BIO-IMAGING RESEARCH INC	LINCOLNSHIRE, IL	SLIT DIGITAL RADIOGRAPHY FOR ANALYSIS OF BOND DEFECTS IN ROCKET MOTORS
201	11	PDA ENGINEERING	COSTA MESA, CA	PHYSICALLY BASED FAILURE CRITERIA FOR CARBON-PHENOLIC MATERIALS
202	11	IMATRON INC	SAN FRANCISCO, CA	ASSESSMENT OF MATERIALS IN SOLID ROCKET MOTORS BY REAL-TIME CT
203	11	ERGO-TECH SYSTEMS INC	TUJUNGA, CA	COMPUTER SIMULATION OF TRANSIENT OPERATION OF SMALL BIPROPELLANT ENGINES
204	12	RADIATION MONITORING DEVICES	WATERTOWN, MA	SOLID STATE NEUTRON DOSIMETER FOR SPACE APPLICATIONS
205	12	IOMED INC	SALT LAKE CITY, UT	TRANSDERMAL DRUG DELIVERY SYSTEM FOR APPLICATION IN SPACE FLIGHT
206	12	EASTERN ANALYTICAL INC	COLLEGE PARK, MD	SELECTIVE ENRICHMENT OF CALCIUM STABLE ISOTOPES USING LASER TECHNIQUES
207	12	UMPQUA RESEARCH COMPANY	MYRTLE CREEK, OR	A REAGENTLESS SEPARATOR FOR REMOVAL OF INORGANIC CARBON FROM SOLUTION
208	12	ADA TECHNOLOGIES INC	ENGLEWOOD, CO	INCIPIENT COMBUSTION MONITOR FOR ZERO GRAVITY ENVIRONMENTS
209	12	RESOURCE TECHNOLOGIES GROUP	MORGANTOWN, WV	THIN MEMBRANE SENSORS
210	12	LYNNTECH INC	COLLEGE STATION, TX	SOLID POLYMER ELECTROLYTE-BASED ELECTROLYZERS FOR WATER RECLAMATION POST-TREATMENT
211	12	UMPQUA RESEARCH COMPANY	MYRTLE CREEK, OR	ELECTROCHEMICAL WATER RECOVERY PROCESS FOR DIRECT REMOVAL OF IMPURITIES
212	12	FOOD AND AGROSYSTEMS INC	SUNNYVALE, CA	METHODOLOGIES FOR PROCESSING PLANT MATERIALS INTO ACCEPTABLE FOOD ON A SMALL SCALE
213	12	CHI SYSTEMS INC	SPRING HOUSE, PA	CAPTURNG SPACE CREW REPRESENTATIONS OF CONTROL SYSTEMS WITH MULTIDIMENSIONAL SCALING
214	12	MOCO INC	SCITUATE, MA	OPTIMAL WORKSPACE DESIGN
215	12	FLORIDA MAXIMA CORP	WINTER PARK, FL	PERFORMANCE OF GROUPS IN EXTREME ENVIRONMENTS: A META-ANALYTIC INTEGRATION
216	12	APTEK INC	COLORADO SPRINGS, CO	AUTOMATION OF STOWAGE

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217	12	PHOTOMETRICS LIMITED	TUCSON, AZ	CHARGE-COUPLED DEVICE SENSORS FOR ELECTRONIC STILL PHOTOGRAPHY
218	12	SARCOS RESEARCH CORP	SALT LAKE CITY, UT	USING ROBOTS IN THE TESTING OF NASA EVA SPACE SUITS
219	12	BEND RESEARCH INC	BEND, OR	MEMBRANE-BASED HIGH-PRESSURE GAS-DEHYDRATION MODULE
220	12	UMPQUA RESEARCH COMPANY	MYRTLE CREEK, OR	THERMALLY DESORBABLE TOXIN AND ODOR CONTROL CARTRIDGE
221	12	NEW HORIZONS DIAGNOSTICS	COLUMBIA, MD	DEVICE FOR SAMPLE COLLECTION AND RAPID IMMUNOLOGICAL IDENTIFICATION OF BIOLOGICAL SPECIMENS
222	12	CHEMICAL TESTING & CONSULTING	BOSTON, MA	CHEMICAL SENSOR SYSTEM FOR THE IDENTIFICATION OF ORGANIC COMPOUNDS IN WATER
223	12	STAR ENTERPRISES INC	BLOOMINGTON, IN	AUTOMATED FOOD DELIVERY TO RODENTS IN SPACE
224	12	AXIOMATICS CORP	CAMBRIDGE, MA	REMOTE MOISTURE SENSOR TO CONTROL IRRIGATION OF PLANTS IN SPACE
225	12	GEO CENTERS INC	NEWTON CENTRE, MA	TRACE CONTAMINANT VAPOR MONITORS
226	12	BIOTRONICS TECHNOLOGIES INC	WAUWATOSA, WI	FIBER FLUOROMETRY FOR ON-LINE CHEMICAL ANALYSIS OF NUTRIENT SOLUTIONS
227	12	NUMEDLOC	BRYN MAWR, PA	ANATOMICAL IMAGE ANALYSIS TECHNIQUES
228	13	FEMTOMETRICS	COSTA MESA, CA	A REAL TIME PARTICLE FALL-OUT MONITOR
229	13	TPL INC	NEWPORT BEACH, CA	A REPAIR COATING FOR CRYOGENIC TRANSFER LINES
230	13	OPHIR CORPORATION	LAKEWOOD, CO	A NOVEL LASER SYSTEM FOR FORECASTING AND MITIGATING LIGHTNING STRIKES
231	13	FWG ASSOCIATES INC	TULLAHOMA, TN	INSTRUMENTED ROCKET WIND PROFILER
232	13	ENSCO INC	MELBOURNE, FL	METEROLOGICAL MONITORING SYSTEM
233	13	AEROSPACE DESIGN & DEVELOPMENT	NIWOT, CO	SUPERCRITICAL CRYOGENIC SELF-CONTAINED BREATHING APPARATUS
234	13	AERODYNE RESEARCH INC	BILLERICA, MA	TEMPERATURE/SHOCK POSITION SENSOR FOR HIGH PRESSURE OXYGEN SYSTEMS
235	13	ARACOR	SUNNYVALE, CA	AUTOMATED RADIATION/RELIABILITY VLSI QUALIFICATION
236	14	SCS TELECOM INC	PORT WASHINGTON, NY	POWER AND BAND WIDTH EFFICIENT DIGITAL COMMUNICATIONS
237	14	OPTRON SYSTEMS INC	BEDFORD, MA	AN ELECTRO-OPTIC MODULATOR FOR LASER WAVEFRONT CORRECTION AND POSITIONING IN SPACE
238	14	MICROWAVE MONOLITHICS INC	SIMI VALLEY, CA	MONOLITHIC GALLIUM ARSENIDE UHF IF SWITCH MATRIX FOR SPACE STATION APPLICATIONS
239	14	PHONON CORP	SIMSBURY, CT	SURFACE ACOUSTIC WAVE SPECTRAL LIMITER FOR NARROW BAND INTERFERENCE SUPPRESSION
240	14	GALAXY MICROSYSTEMS INC	AUSTIN, TX	HIGH SPEED DIGITAL DATA TRANSMISSION
241	14	MICROWAVE MONOLITHICS INC	SIMI VALLEY, CA	ADVANCED MONOLITHIC GALLIUM ARSENIDE RECEIVER FRONT END FOR SPACECRAFT TRANSPONDERS
242	14	Q-DOT INC	COLORADO SPRINGS, CO	HIGH INSTANTANEOUS DATA RATE BURST SIGNAL RECEIVER
243	14	SPIRE CORPORATION	BEDFORD, MA	HIGH-INDIUM-CONTENT HIGH ELECTRON MOBILITY TRANSISTORS FOR RF COMMUNICATIONS DEVICES
244	14	LIGHTWAVE ELECTRONICS CORP	MOUNTAIN VIEW, CA	EFFICIENT AND LOW-TIMING-JITTER PULSED LASERS FOR SPACE COMMUNICATIONS
245	15	INTERSONICS INC	NORTHBROOK, IL	STABILIZED ELECTROMAGNETIC LEVITATOR
246	15	MICROGRAVITY SYSTEMS INC	BROWNSBORO, AL	PERMANENT MAGNET FLIGHT FURNACE
247	15	SOUTHWEST SCIENCES INC	SANTA FE, NM	COMBUSTION DIAGNOSTICS FOR MICROGRAVITY RESEARCH USING NEAR-INFRARED DIODE LASERS
248	15	SCHWARTZ ELECTRO-OPTICS INC	CONCORD, MA	SPACE-QUALIFIED LASER FOR MICROGRAVITY EXPERIMENTS
249	15	BRIMROSE CORP OF AMERICA	BALTIMORE, MD	NOVEL 'IN SITU' TECHNIQUE TO VISUALIZE CONVECTION ON SOLID-LIQUID INTERFACES
250	15	CREARE INC	HANOVER, NH	NUMERICAL MODELING OF PARTICLE FORMATION AND GROWTH DURING CHEMICAL VAPOR DEPOSITION
251	15	TECHNICAL INTEGRATION & DEV	BILLERICA, MA	AUTOMATIC FAULT DETECTION AND FAILURE PREDICTION FOR SPACECRAFT SYSTEMS

*U.S. G.P.O. 1990-721-952